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DEPARTMENT OF THE INTERIOR

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No. 15

NOTES ON THE MESOZOIC AND CENOZOIC PALEONTOLOGY OF CALIFORNIA

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J. W. POWELL DIRECTOR

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CHARLES A. WHITE M. D.

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NOTES ON THE MESOZOIC AND CENOZOIC PALEONTOLOGY OF CALIFORNIA.

By Charles A. White.

GENERAL REMARKS.

Having been for a number of years engaged in the study of those Mesozoic and Cenozoic formations of the United States which lie between the one hundredth and one hundred and fourteenth meridians, it became desirable that I should make some comparisons of them with the formations of similar age which are known to constitute important portions of the geological series as it is developed in the Pacific coast region. Dr. G. F. Becker, in charge of the Pacific division of the Survey, in the course of his investigations also found it necessary to the proper elucidation of certain of the problems involved in his work that some special paleontological studies should be made in connection with it. I therefore, by request of the Director, devoted the season of 1884 to such investigations as have a direct bearing upon the Mesozoic and Cenozoic formations of California, extending my field observations to numerous localities within that State and to certain localities in Oregon also. These investigations were pursued in association with Dr. Becker, who gave his attention to the more purely geological questions with which they are intimately connected. The results of our respective studies are published in companion bulletins of the Survey, Nos. 15, (the present one,) and 19.

While only a few months have been given especially to this work upon the Pacific coast, I have had the advantage of a previous acquaintance with the results of the labors of all other authors who have written upon the paleontology of California; and these advantages I deem sufficient warrant for the conclusions which I have reached, and for their publication in the present form. Upon undertaking this work the questions which seemed more especially to demand my attention were, first, the true geological age of the Téjon Group of the California geologists, and its relation to such of the associated groups as they had also recognized, that is, the relation of that group to the Miocene above and to the Chico and Shasta Groups beneath; second, the relation between the Chico and the Shasta Groups; third, the relation of the Shasta Group to the other

Cretaceous formations, and to the so-called Auriferous Slates of California.

One of the principal obstacles to the satisfactory accomplishment of this work has been found in the fact that the fossil faunas of the Pacific coast region differ so greatly from those which are presumably of the same age respectively in other parts of the continent. Indeed, a conspicuous feature of the paleontology of that western region, at least as regards the formations from the Shasta, to the Téjon Group, inclusive, is the great paucity, and perhaps the entire absence, of fossil species in those formations respectively which are identical with any that are found in formations presumably of the same age which lie to the eastward of that region.[1] Similar remarks will also apply to the Miocene and later deposits of the Pacific coast. Furthermore, the Carboniferous fauna of that region, so far as it is known, presents marked differences from that of any of the divisions of the Carboniferous series as it is known in other parts of North America. Therefore, in the paleontological study of the Pacific coast formations one must discuss their respective equivalent formations in other parts of the continent and in other parts of the world mainly with reference to the generic and family types which are represented in their respective faunas. This dissimilarity between the fossil faunas of corresponding formations of the Pacific coast region and of the central and eastern portions of this continent is quite as great as it is between corresponding formations in Eastern North America and Europe. In many cases, indeed, one may discuss questions concerning the equivalencies of formations in Eastern North America and Europe, respectively, with more confidence than similar questions concerning the formations of eastern and western portions of North America.

In discussing the paleontological questions here proposed I shall have frequent occasion to refer to geological structure; and it will be necessary for me to use in this connection the classification of strata which was proposed by the State geological survey of California for that region, and which has become generally accepted by geologists. A portion of that classification, however, was not regarded by the geologists of the California survey as fully established, and it was proposed by them only provisionally. It is proper for me to say in this connection that not only do these provisional portions of that classification still remain unsettled, but that I also find the limits, both faunal and stratigraphical, of a part of the formations which they fully recognized to be indefinite and of doubtful character.

My season's field work upon these formations has been in a good degree satisfactory, because I was able to collect in person many of the species of fossils which characterize the respective groups of strata, and because I was able to verify numerous unpublished observations previously made by Dr. Becker, besides many others which were made still earlier by Prof. J. D. Whitney, the results of which are published in the State Geological Reports of California.[2] In fact I have verified so many of the published observations of Professor Whitney that I do not hesitate to accept his statements in such other cases as I shall find it necessary to refer to in the following discussions.

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[1] Some Chico fossils have, however, been found to the eastward of the Cascade Mountains, in Oregon; but the extent of the formation which contains them there, and its relation to the Cretaceous strata further eastward, is not known. See remarks on subsequent pages concerning the identification of California fossils with Eastern species; also remarks on the separation of contemporaneous Cretaceous faunas.

I find the case somewhat different, however, as regards the work done by Mr. W. M. Gabb in connection with the geological survey of California; but the adverse views which I have formed in relation to it refer much more to the conclusions which he reached than to the published details of his observations and of his descriptive paleontology.[3]

Taking up the subjects which it is proposed to discuss in this article, in the order in which they are mentioned in a previous paragraph, we have first to consider the Téjon Group. In his studies of the Mesozoic and Cenozoic formations of California, Mr. Gabb recognized four groups of strata as referable to the Cretaceous period; and this classification was officially adopted by the geological survey of that State. As one looks through the published writings of Mr. Gabb in relation to the grouping of the California strata, and their age and relations to the recognized groups of North America and Europe, a certain want of harmony appears in regard to the statements which he has made. I think it is only just to say that I regard this as largely due to the modification which his views necessarily underwent during the progress of his work, although he appears not to have made any explicit statements to that effect in any of his later publications. I shall therefore refer more especially to his later utterances, as I find them in the various publications to which he has contributed, especially in Vol. II, Paleontology of California, omitting as far as practicable material reference to his earlier views, although many of the discussions which have arisen in relation to them refer to the latter.

The following paragraphs, copied from Professor Whitney's preface to Vol. II, Paleontology of California, pp. xiii and xiv, give a concise account of those formations in accordance with Mr. Gabb's later views and as they were finally adopted by the State survey. It is these formations alone that I propose to discuss in this article, and I shall consider the other formations of that region only in their relation to these.

1. The Téjon Group, the most modern member, the Division B of Paleontology, Vol. I, is peculiar to California. It is found most extensively developed in the vicinity of

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[2] See Vols. I and II, Paleontology, and Vol. I, Geology of California.

[3] Mr. Gabb's work on the fossils of California is mainly contained in Vols. I and II of the Paleontology of California, but the following papers may be referred to for other discussions which relate to his work in that State: American Journal of Conchology, II, pp. 87–92; V, pp. 5–18; American Journal of Science, (2), XLIV, pp. 226–229; Proceedings of the California Academy of Science, III, pp. 301–306; V, pp. 7–8.

Fort Téjon and about Martinez. From the latter locality it forms an almost continuous belt in the Coast Ranges to Marsh's, 15 miles east of Monte Diablo, where it sinks under the San Joaquin Plain. It was also discovered by different members of the survey at various points on the eastern face of the same range as far south as New Idria, and in the summer of 1866, by Mr. Gabb, in Mendocino County, near Round Valley, the latter locality being the most northern point at which it is yet known. It is the only coal-producing formation in California.

This group contains a large and highly characteristic series of fossils, the larger part peculiar to itself, while a considerable percentage is found to extend down into the next group, and several species still further down into the Chico Group. Mr. Gabb considers it as the probable equivalent of the Maestricht beds of Europe.

2. The Martinez Group is proposed provisionally, to include a series of beds, of small geographical extent, found at Martinez and on the northern flank of Monte Diablo. It may eventually prove to be worthy of ranking only as a subdivision of the Chico Group.

3. The Chico Group is one of the most extensive and important members of the Pacific coast Cretaceous. Its exact relations with the formation in Europe have not been fully determined, though it is on the horizon of either the Upper or Lower Chalk and may prove to be the equivalent of both. It is extensively represented in Shasta and Butte Counties and in the foot-hills of the Sierra Nevada as far south as Folsom, occurring also on the eastern face of the Coast Ranges bordering the Sacramento Valley, at Martinez, and again in Oristimba Cañon, in Stanislaus County. It includes all the known Cretaceous of Oregon and of the extreme northern portion of California, and is the coal-bearing formation of Vancouver's Island.

4. The Shasta Group is a provisional name, proposed to include a series of beds of different ages, but which, from our imperfect knowledge of the subject, cannot be separated; it includes all below the Chico Group. It contains fossils, seemingly representing ages from the Gault to the Neocomian, inclusive, and is found principally in the mountains west and northwest of the Sacramento Valley. Two or three of its characteristic fossils have been found in the vicinity of Monte Diablo, and one of the same species has been sent from Washington Territory, east of Puget Sound. Few or none of its fossils are known to extend upwards into the Chico Group.

THE CHICO-TÉJON SERIES.

It appears from Mr. Gabb's later publications that he recognized that all the strata from the base of the Chico Group to the top of the Téjon form an unbroken portion of the great geological series. And yet, with perhaps the exception of his Martinez division, which he proposed provisionally, he always discussed those divisions as if they were as distinctly definable as geological formations usually are. Geologists will probably always find it convenient to retain the names Téjon and Chico for the upper and lower portions of this series, respectively, but I have not been able to find any good reason for retaining the name Martinez Group for any portion of it. I shall therefore reject the Martinez Group so far as my own discussions of the series here referred to are concerned.

The first published fossils of that series of strata which afterward received from the California survey the name of Téjon Group were obtained by parties of the Pacific Railroad surveys, some thirty years ago. These fossils were described by Mr. T. A. Conrad in the reports of that survey, and by him referred to the Eocene Tertiary.[4] So far as I am aware, he never changed his mind as to the geological age of these fossils, nor of the group of strata from which they and many others were afterward obtained. On the contrary, he repeated the publication of his views[5] and strongly contended for their accuracy. Mr. Gabb alone, so far as I am aware, has published any of the fossils of the Téjon Group as of Cretaceous age; and this he did with a positiveness of assertion which, while it left no doubt as to his views, is only warranted in cases where the evidence is abundant and unquestionable from any reasonable standpoint.[6]

The publication of Mr. Gabb's views with the sanction and in the reports of the geological survey of California gave the matter so much the air of authority, that various authors accepted those views as to the Cretaceous age of the Téjon Group, and for several years after Conrad's death it was not seriously called in question.

Professor Dana, however, has practically called those views in question, suggesting that the Téjon Group is of Eocene age, and probably equivalent with the Laramie Group.[7]

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[4] See Pacific Railroad Reports, Vol. V, pp. 317–329.

[5] See Amer. Jour. Sci., (2), XLIV, pp. 376–377; Amer. Jour. Conch., I, pp. 362–365; II, pp. 97–100; Smithsonian Check-List of Eocene Fossils.

[6] See especially Proc. California Acad. Sci., III, p. 301.

[7] See Dana's Manual of Geology (1876), p. 491.

In 1882, however, Prof. Angelo Heilprin, having access to the greater part of the type specimens of Mr. Gabb's species of the Téjon Group, took up the study of the subject, and reached the conclusion that this group, as it was recognized by the California survey, is of Eocene Tertiary and not of Cretaceous age, and published his views in the Proceedings of the Academy of Natural Sciences of Philadelphia.[8]

This is the most eloborate and important paper that has been written upon the subject, and, as it accords mainly with the conclusions which I have reached, the reader is referred to it for many details which it is impracticable to present in this article. In that publication Professor Heilprin groups together all the species which have been referred to the Téjon Group by Mr. Gabb, and shows that, although fragments of *Ammonites* have been found among them, being such as are usually referred to the Cretaceous, much the larger part of the species are such as are commonly regarded as distinctively tertiary.

A few months after the publication of Professor Heilprin's paper, Prof. Jules Marcou published in the Bulletin of the Geological Society of France, an article on the geology of California, as the results of his personal studies in that State several years ago. In this article Professor Marcou also contends for the Tertiary age of the Téjon Group.[9]

The fossils published by Mr. Gabb in the two volumes of the Paleontology of California as characterizing the Téjon Group comprise a large number of molluscan species. A small part of those species are so suggestive of a Cretaceous fauna, according to the hitherto accepted standards, that no paleontologist, viewing them separately, would hesitate to pronounce the strata from which they came as of Cretaceous age. Others of these fossils belong to genera which have so wide a range in time, that they are not relied upon by paleontologists as definite indices of geological periods. But the greater part of these published Téjon species belong to genera which paleontologists are generally agreed upon as indicating the Tertiary age of the strata which bear them, as has been shown by Professor Heilprin.

Since in all other parts of the earth where the Mesozoic and Cenozoic strata have been fully studied the boundary, both faunal and stratigraphical, between the Upper Cretaceous and Lower Tertiary has been found to be well defined, many persons, apparently regarding that condition as the natural or normal one, have believed that the commingling of the Tertiary and Cretaceous types which was shown by Gabb's publications really did not originally exist in nature, but that it was due to some accidental or adventitious causes.[10] While the commingling of Cretaceous with Tertiary types in the same strata probably does not exist to as extreme a degree as seems to be indicated in some of Mr. Gabb's earlier writings, I am satisfied that such a commingling does exist to a large extent, as before indicated, and that an alternate commingling of species exists throughout the whole of the Chico-Téjon series. That the upper part of this series is almost purely of Eocene character, and that the lower part is as distinctly Cretaceous, is, I think, undeniable. Still, I am satisfied that no definable horizon exists in that series which will separate all the Cretaceous from the Teriary, and that no lines can be drawn which will separate a median portion of the series, in which all the commingling of types takes place.

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[8] See Proc. Acad. Nat. Sci. Philad. for 1882, pp. 195–214. This paper is also reproduced in Professor Heilprin's Contributions to the Tertiary Geology and Paleontology of the United States, 4°, Philadelphia, 1884.

[9] See Bulletin de la Société Géologique de France, (3), t. XI, 1883, pp. 407–435.

[10] See Conrad's remarks, Am. Jour. Conch., II, pp. 98 *et seq.*

In all the publications of the California survey the fact is made apparent that no distinct line of demarkation, either paleontological or stratigraphical, has been recognized in separating the Téjon from the Chico Group; and yet Mr. Gabb constantly refused to admit that the California strata in question might really constitute a continuous series, embracing both Cretaceous and Tertiary strata.[11] Indeed, at that time such wiews would probably have found little favor among paleontologists if he had entertained and published them. He seems to have considered it necessary that any unbroken series of strata, however great, should be referred to one and the same period; and in this instance he chose the Cretaceous; while Professor Marcou seems to have chosen the Tertiary, and with quite as much if not more reason.

The results of my field work in California, including an examination of the localities from which Mr. Gabb obtained many of his type specimens of both Téjon and Chico species, have convinced me of the general accuracy of his statements as to the horizons from which his fossils came when he collected them himself. They have also confirmed my opinion that the unbroken series of strata which comprise the Chico and Téjon Groups of the California geologists repesent together the closing epoch of the Cretaceous period and the opening or Eocene epoch of the Tertiary.

The most satisfactory illustration of the intimate stratigraphical connection between the Chico and Téjon Groups which I have examined occurs near New Idria, Fresno County, California, where an extensive series of strata embracing these two groups is fully exposed. My attention was called to this series by Dr. Becker, who had studied it as a part of the geology of the New Idria district, which he has investigated in connection with his work on the quicksilver deposits of the Pacific coast. The strata in question had also been studied by members of the State geological survey of California, and they embrace one or more of the localities from which Mr. Gabb obtained the types of some of his Téjon species of fossils. This series of strata is there well exposed, being comparatively free from soil or *débris;* is composed mainly of sandstones and sandy shales, and lies on the northern slope of the range of hills, the central mass of which is composed of the metamorphic strata which bear the quicksilver deposits of the New Idria mines. They dip to the northward, the angle of dip being high near their contact with the metamorphic series, upon which they rest unconformably, as shown by Dr. Becker; but the dip materially diminishes to the northward. From its contact with the metamorphic rocks the series in question extends northward a distance of about four miles, where it is apparently terminated by a fault, so that its connection with the Eocene is not there shown. From the contact with the metamorphic rocks before mentioned the thickness of this whole series of strata is estimated by Dr. Becker to be about 10,000 feet, and in my opinion it is no less.

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[11] See especially Proc. Cal. Acad. Nat. Sci., III, pp. 302.

Dr. Becker, with his assistants, carefully searched this whole series of strata for the purpose of collecting its fossils, and also to ascertain the conditions of its stratification. Upon the latter subject he reached the opinion that this whole assemblage of strata, nearly two miles in thickness, forms one continuous series from top to bottom, and that the sedimentation which resulted in the production of these strata was uninterrupted from the beginning to the end of the time in which it occurred. After a somewhat careful personal study of this series upon the ground, I have accepted Dr. Becker's conclusions as to the points just mentioned.

Although this New Idria series is understood to be practically an unbroken one, there is near its middle a recognizable change in the aspect of the strata, so that in appearance, and to some extent in the character of the stratification, the upper half differs from the lower half. It is upon this indistinctly definable horizon that Dr. Becker divided the series into two groups, for the purpose of arranging the results of his studies of them. So far as can be determined, this indistinct line accords with the necessarily artificial division that has been made of the series into the Chico and Téjon Groups, since the series is recognized as containing only these two groups, and the line of demarkation between them, as before shown, cannot be expected to be distinct. Fossils were collected by Dr. Becker's party from various horizons in the series, but in a large portion of it none were found, and those from the lower or Chico portion are very few. These latter are, however, of characteristic types, being species of *Ammonites*, *Baculites*, *Trigonia*, *Inoceramus*, and *Lima*. It is proper to mention that in this New Idria series of strata no commingling of the Cretaceous species above referred to with Tertiary types of fossils was actually observed; but very few fossils of any kind were obtained at this locality, especially in the lower portion of the series. Still, the intimate relation of the Chico and Téjon Groups for this particular locality is well shown by the unbroken character of the series of strata which here constitutes both groups.

The exact equivalents of this New Idria series of rocks are found in the vicinity of Martinez, in Contra Costa County, as well as in other parts of California. At Martinez and other localities a commingling of Cretaceous and Tertiary types such as has already been referred to actually occurs; but in all cases the Tertiary types appear to increase towards the upper part of the series and the Cretaceous types towards the lower part. In other words, it appears that the base of the series has a preponderance of Cretaceous types, and the upper part a preponderance of Tertiary.

Besides the evidence afforded by the character of the contained fossils, the opinion that the Téjon Group really represents the Eocene is further supported in that no other representative of the strata of that epoch has been discovered in California, and also the Miocene strata everywhere rest conformably upon the Téjon. This conformity was recognized by the members of the State geological survey of California, and it has also been observed in numerous cases by Dr. Becker, as well as in several instances by myself. One of these observations I made at the well-known Téjon and Miocene locality at the head of Vallecitos Cañon, near the place mentioned as "Griswold's" in the California reports, which is only a few miles from the New Idria locality, just referred to.[12] I there satisfactorily traced the strata from one formation to the other, and found that not only is the conformity of the two formations with each other clearly apparent, but no break in the order of stratification could be detected between those layers which contain characteristic Téjon fossils, on the one hand, and those which contain equally characteristic Miocene fossils, on the other. In short, I found no room there for the existence of any Eocene strata other than the Téjon.

The character of the fossils which are found in the formation thus resting conformably upon the Téjon is such that their Miocene age has never been called in question; and the California geologists who regarded the Téjon Group as of Cretaceous age necessarily considered the Eocene as unrepresented among the strata of that State. It is proper to say, however, that the difference between the Téjon and Miocene faunas, as regards specific forms, is well marked; so that, so far as I am aware, none of the species of the former pass up into the latter formation. A few of the species of each of the two formations are closely related, and it is possible that some of them may yet prove to be specifically identical. While the Miocene strata of California seem to have been deposited upon the Téjon Group by continuous sedimentation, these two groups are not so intimately related by their fossils as the Téjon and the Chico Groups are. Still, I am of the opinion that this faunal difference between the Téjon and the Miocene strata does not necessarily represent a material difference of time.

From the foregoing remarks it will be seen that there exists in California a comformable and intimately connected series of strata representing the latest epoch of the Cretaceous period to the Miocene, inclusive. The base of this series, as shown by Dr. Becker, rests unconformably upon all the other rocks with which it has been found in contact, and, as shown by the California reports, the Pliocene rests unconformably upon the Miocene.

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[12] See Geology of California, Vol. I, p. 56.

No proposition seems to me to be more reasonable than that wherever any portion of the great geological series is complete the line of demarkation between any of the formations must necessarily be indistinct, and that there will be a commingling of the species which any two adjacent formations contain, upon both sides of any such line as may be recognized. Such a condition of things would as naturally exist in strata representing the confines of any two geological ages as in the case of those of any two formations of any one age. Therefore, if the geological series is complete, there ought to be no greater break between the Cretaceous and the Tertiary than between any of the subdivisions of either. It is nevertheless true that geologists have always recognized a marked paleontological break between the uppermost Cretaceous and the lowermost Tertiary strata, both in this country and in Europe. Sir Charles Lyell remarks as follows upon this subject, and the statements of other European authors are to the same effect:

> The marked discordance in the fossils of the Tertiary as compared with the Cretaceous formations has long induced many geologists to suspect that an indefinite series of ages elapsed between the respective periods of their origin. Measured, indeed, by such a standard, that is to say, by the amount of change in the fauna and flora of the earth effected in the interval, the time between the Cretaceous and the Eocene may have been as great as that between the Eocene and Recent periods.[13]

The Maestricht, Faxoe, and other beds of Europe, although they are intermediate between the Upper Chalk and the Eocene, are too closely related by specific and generic forms to the Chalk to be regarded as separate from the Cretaceous proper. Their faunal relations to the Eocene are also too remote to allow of their being regarded as in any proper sense transitional between the Cretaceous and Tertiary. In New Zealand, however, it appears probable from the reports of the Government geological surveys that there is in those great islands a true transition from the Cretaceous to the Tertiary, similar to that which occurs in California.

I think the evidence which has been adduced to show the Eocene age of the upper or Téjon portion of the Chico-Téjon series is as conclusive as any evidence of that kind can be. Now, if we apply the paleontological standard for indicating the age of formations which is generally accepted by geologists, we necessarily refer the fossils of the lower or Chico portion of that series to the Cretaceous. The question then arises: to what portion of the full Cretaceous series, as it is recognized in other parts of the world, is the Chico Group really equivalent? If the Téjon Group is Eocene, it is plain that the Chico Group represents the upper portion of the Cretaceous, and it necessarily represents the very latest portion of that period. My opinion, therefore, is that it is, at least in part, later than any formation that has yet been referred to the Cretaceous period either in Europe or in America, and that it practically fills the gap which is indicated by the passages just quoted from Sir Charles Lyell.

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[13] See Lyell's Elements of Geology (1871), p. 281.

An examination of the figures and descriptions of the fossils which Mr. Gabb has referred to the Chico Group, together with his catalogue of California Cretaceous fossils,[14] shows that while a considerable portion of them, especially the Cephalopoda, are of types which indicate their Cretaceous age, a large part of them are of genera which are known to range from the early Cretaceous to the present time, and some of them belong to genera which are generally accepted as not older than the Tertiary. Therefore there appears to be no inherent reason why this Chico fauna, even as it is represented by Mr. Gabb, should not be regarded as belonging to the very latest portion of the Cretaceous period. The fact that one or two Mesozoic types of Cephalopods pass up from these strata into those of the Téjon portion does not necessarily prove that the latter ought also to be referred to the Cretaceous, any more than the discovery of *Ammonites* in the Carboniferous of Texas and of India ought to require us to refer those strata to the Mesozoic.

The intimate relation to each other of all the strata of this great Chico-Téjon series, as shown by the mixed character of its fossils, is very perplexing when that condition is considered in relation to the established taxonomy of the formations, but it is very suggestive when considered with reference to a search after the complete sequence of geological events. Indeed, such a condition of things is what one ought to expect to find somewhere; but hitherto no other part of the world, if we except New Zealand, has furnished so striking an example of the intimate connection of two geological ages, or at least of such connection between the Cretaceous and the Tertiary.

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[14] See Vols. I and II, Paleontology of California, for the figures and descriptions, and Vol. II, pp. 209-254, for the catalogue.

THE SHASTA GROUP.

When Vol. I of the Paleontology of California was published it appears that the Shasta Group was not recognized by the California geologists. At that time Mr. Gabb divided the rocks which he referred to the Cretaceous period into two portions, which he designated respectively as Divisions A and B.[15] His line of separation between these two divisions was the same as that by which he afterwards separated his Téjon and Chico groups.[16] A part of the fossils which he published in Vol. I as belonging to Division A belong really to the Shasta Group,[17] the separate existence of which he had not then recognized. He did not then recognize these Shasta fossils as belonging to the age of the Gault or Neocomian, as he afterwards did, but he regarded all the Cretaceous strata of California as representing the epoch of the White Chalk of Europe.[18] For this classification of the California strata, however, he afterward, in Vol. II, substituted that which has already been quoted on page 9. In Vol. II the Shasta Group is proposed to receive all the Cretaceous strata of that region which are older than the Chico Group. The entire separateness of the Shasta from the Chico Group is there recognized, and it is also stated to embrace strata of different epochs, probably representing a range from the Gault to the Neocomian.[19] This latter view I am disposed to adopt as at least approximately correct, although it is not yet clear what division ought to be made of the strata that have been grouped together under the name of the Shasta Group; but this question will be discussed further on.

Whatever may be the relation of the Shasta strata among themselves, it seems to be certain that there is an abrupt hiatus, both stratigraphical and paleontological, between the Shasta Group and the Chico Group, the former representing a portion of the period not later than its middle, and the latter its closing portion. It has been generally understood that the marine Cretaceous deposits of the United States, as they are found in the Atlantic, Gulf border, and interior regions, represent only the Upper Cretaceous of Europe, none of them probably being any older than, if so old, as the Gault. If, then, the Chico is, as it is here assumed to be, later than any other Cretaceous strata known in Europe or America, and the Shasta Group is as old as the Gault, or older, we have a hiatus in the California Cretaceous series which is equal to all the time in which all the other known Cretaceous deposits of the United States were formed. Although such a conclusion seems to be a plausible one from our present methods of reasoning, we unfortunately lack the proof of it which specific identity of Cretaceous fossils on each side of the Sierras would afford. It is proper in this connection also to state that Mr. Gabb reports three species of Cephalopoda as common to the Shasta and Chico Groups, namely, *Ammonites batesii*, *A. remondii*, and *Ancyloceras lineatus*.[20] If Mr. Gabb is correct in these references, it seems to point to a closer faunal relation between the Chico Group and the Horsetown beds of the Shasta Group than would be expected were the hiatus between them as great as is implied by referring the latter to the age of the Gault and the former to the latest portion of the Cretaceous period.

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[15] See Paleontology of California, I, p. xix, and Proceedings of the California Academy of Sciences, III, p. 302.

[16] See Paleontology of California, II, p. xiii.

[17] See especially the Cephalopoda, published in Vol. I, Paleontology of California.

[18] See Paleontology of California, I, p. xix.

[19] See Paleontology of California, II, p. xiv.

The strata which received the name of Shasta Group from the geologists of the State survey of California occupy only a few isolated areas in that State. Each of these areas is not only of small geographical extent, but the strata in every case are either unconformable with the rocks both above and below them, or they are so much disturbed that their stratigraphical relations are obscure. The strata of these separated portions of the Shasta Group of California, judged by the fossils which they respectively contain, seem to represent at least two epochs of the Cretaceous period. Our knowledge of those strata and their fossils is not quite sufficient to warrant the formal separation of the former into two distinct groups, in the sense in which that name for assemblages of strata is generally used, but two divisions are plainly indicated by the fossils. I shall therefore, for the present, retain the name of Shasta Group in the general sense in which it was used by the geologists of the California survey; but for the purpose of convenience in the references which I must necessarily make in this article to those two divisions, I shall designate them as the Horsetown beds and the Knoxville beds, respectively. These names are suggested by the two localities from which the best collections of the fossils of each of these two divisions were obtained.

The Horsetown beds have been found mainly in Shasta County and the Knoxville beds mainly in Lake, Colusa, Contra Costa, and Santa Clara Counties. These two divisions have never been found in contact, nor under such circumstances as will enable us to say with certainty which of the two is the older. From paleontological considerations, however, the character of which will appear further on, I am inclined to regard the Knoxville beds as older than the Horsetown beds. The latter, although they have a much less known geographical extent, certainly contain a more abundant and varied fauna than the former. It is especially rich in the Cephalopoda, as will appear by referring to the California reports, where the fossils of this division are recorded as coming from "the North Fork of Cottonwood Creek, Horsetown," etc. Furthermore, many of the types which the fauna of the Horsetown beds embraces are such as paleontologists use with more confidence as indices of the geological position of the strata containing them than they do any of those which are embraced by the fauna of the Knoxville beds, as it is at present known.

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[20] Mr. H. W. Turner has also found an Ammonite in the Chico Group near Monte Diablo which, if not specifically identical with *Ammonites stoliczkanus* Gabb, is very closely related to it. The original specimens came from the Shasta Group.

The following species which were published by Mr. Gabb in the California reports are regarded as having come from the Knoxville beds at different localities in California. The interrogation marks after three of them express a doubt as to the correctness of my identification of the species, Mr. Gabb having obtained his type specimens of those species from the Horsetown beds. All the other species which are mentioned in Gabb's Catalogue of California Cretaceous Fossils as belonging to the Shasta Group[21] I regard as having come from the Horsetown beds.

The following is a list of the species just referred to:

Ammonites ramosus Meek ?
Belemnites impressus Gabb.
Palætractus crassus G.
Cordiera mitræformis G.
Atresius liratus G.
Potamides diadema G. ?
Ringinella polita G.
Liocium punctatum G.
Modiola major G.
Aucella piochii G.
Rhynchonella whitneyi G.
Lima shastaensis G. ?
Pecten complexicosta G.

In addition to these published species the following have been generically recognized among the collections which have been obtained by Dr. Becker and his party from Knoxville, Cal., all the specimens of which are, however, too imperfect for specific determination: *Ammonites ?*, *Margarita ?*, *Dentalium*, *Arca*, *Nuculana*, and *Rhynchonella*. Besides all these forms there are fragments among the collections from Knoxville which indicate two or three other molluscan species which are not considered in my enumeration of the fauna of the Knoxville beds. The specimens which have been referred to as probably representing a species of *Ammonites* are only a few small fragments, which show only portions of the sides and periphery of the shell. These seem to indicate a species related to the *A. newberryi* of Meek. The *Dentalium* is probably undescribed, as are also probably the *Arca* and *Nuculana*. The *Rhynchonella* is apparently an undescribed species, and seems to be identical with one which I discovered last summer at Horsetown.[22] The collection contains only one fragment of the shell which I have referred with doubt to *Margarita*.

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[21] See Paleontology of California, II, pp. 209–254.

The specimens of *Ammonites* which in the foregoing list of published species I have referred with doubt to *A. ramosus* Meek consist only of the small inner whorls, none of them reaching an inch in diameter. The form, surface markings, and septa of the shell, so far as these characters are shown by the Knoxville specimens, seem, however, to agree well with those of the species as it is described by both Meek and Gabb. Meek's type specimens came from Vancouver's Island, but Gabb identified the species in the Horsetown beds of the Shasta Group of California.[23] The specimens of the shell which in the foregoing list I refer with doubt to the *Potamides diadema* of Gabb are imbedded in compact rock, so that all its characters cannot be observed. They are probably identical with Gabb's species, which he describes as coming from the Horsetown beds. Finally, so far as the specific identity of any *Belemnites* can be determined, there seems to be comparatively little reason to doubt that the specimens which have been found in the Horsetown and Knoxville beds, respectively, and referred to *Belemnites impressus* Gabb, are specifically identical.

Comparing these nineteen species of fossils now known to exist in the Knoxville beds with those from the Horsetown beds, or, in other words, with all the other species which Gabb refers to the Shasta Group,[24] we find that all except six of them are certainly different from any of the latter. One of these six, the *Ammonites newberryi ??*, offers only a mere suggestion of identity; four are probably, but not certainly, identical, namely *Ammonites ramosus ?*, *Potamides diadema ?*, *Lima shastaensis ?*, and *Rhynchonella* ——— *?;* and the specific identity of one, *Belemnites impressus*, has been regarded as certain. Detracting somewhat from the certainty of the last identification we have the fact that the *Belemnites*, as a rule, do not present salient or even satisfactory features by which to determine specific differences.

The dissimilarity between the faunas of the Knoxville and the Horsetown beds is still further shown by the abundance of *Aucella* in the former and its absence from the latter, so far as is now known, and also by the greater abundance of the species which characterize the Horsetown beds and their general dissimilarity when compared with the few species which are yet known from the Knoxville beds. It is possible that the *Aucella* may yet be found to range up into the Horsetown beds, but even in that case there would remain a material difference between the faunas of the two divisions.

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[22] This form is closely like the *R. oxyoplicata* of Fischer, from the Jurassic of Moscow.

[23] See Bull. U. S. Geol. Sur. Terr. (1876), II, p. 371, Pl. V, Fig. 1; also Paleont. California, I, p. 65, Pl. XI, Fig. 13, and Pl. XII, Fig. 12*b*.

[24] See Gabb's Catalogue Paleont. California, II, pp. 209–254.

These differences between the faunas of the Knoxville and the Horsetown beds seem to indicate plainly that they were not synchronously deposited; but, as before remarked, there is yet no known stratigraphical proof as to which is the older. The character of the fossils of the respective faunas seems to indicate, however, that the Knoxville are older than the Horsetown beds; that is, the fossils of the Horsetown beds appear to represent the Gault, while the presence of *Aucella* in the Knoxville beds only would seem to indicate an age for them at least as early as the Neocomian. Furthermore, the affinities of some of the fossils of the Horsetown beds are with those of certain of the later Cretaceous formations to the eastward of the Sierras, while no such affinities have been recognized for any of the Knoxville fauna, with the doubtful exception of *Ammonites complexus*. In this article I shall take the foregoing view of the relative ages of the Knoxville and the Horsetown beds, although it implies the probable existence of a considerable hiatus between the two divisions of what is now known as the Shasta Group.

RELATIONS OF THE SHASTA GROUP TO STRATA BEYOND THE LIMITS OF CALIFORNIA.

Certain of the species which characterize the strata of the Shasta Group in California have been recognized among the collections which have been reported by different persons from Washington Territory and British Columbia, and also from Alaska and the Aleutian Islands. But none of the species of that group have been found in any North American strata to the eastward of the Pacific coast region, if we except Greenland. While it is probable that the Horsetown beds of California are represented in those northern localities which have been referred to, it is more especially the equivalent of the fauna of the Knoxville beds that has been recognized as existing there. This recognition is mainly through the identification, among the collections which have been made there, of the *Aucella*, which so strongly characterizes the Knoxville division of the Shasta Group in California. Specimens which I regard as specifically identical with the form which Mr. Gabb published under the name of *Aucella piochii* have been presented to the Survey by Prof. Thomas Condon, which he collected at Puget Sound, Washington Territory. Mr. Whiteaves refers to the same species as being abundant at Tatlayoco Lake and other places in British Columbia;[25] and Professor Eichwald, Dr. P. Fischer, and myself have published forms which I regard as specifically identical with it, from different parts of Alaska.

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[25] See Trans. Roy. Soc. Canada, Sec. IV, 1882, p. 84.

Among the fossils collected in Alaska by Peter Doroschin, Eichwald[26] recongized all the forms of *Aucella* which Keyserling had published as occurring in Russia, namely, *A. concentrica* Fischer, *A. mosquensis* Von Buch, *A. pallasi* and *A. crassicollis* Keyserling. The last two he regards as only varieties of *A. concentrica.* Dr. Fischer[27] recognized only one species among Pinart's Alaskan collections, which he referred to *A. concentrica.*

I also recognized only one species among the collections brought from Alaska by Mr. Dall. . Although the specimens were numerous, and presented quite a wide variation of form, I regarded them all as representing a variety of *Aucella concentrica.*[28] Mr. Whiteaves (loc. cit.) recognized only one species among the collections from British Columbia, and this he referred to *Aucella mosquensis.*

In the Knoxville beds of California there are two recognizable varieties of *Aucella*, which, while they are connected together more or less closely by intermediate forms, are still quite different in extreme examples. It is usually the case also that one variety will be found to prevail in certain layers of rock sometimes almost exclusively, and the other variety in other layers.

Adult examples of one of these varieties are large, robust, and often inflated. These I regard as approaching the typical forms of *A. concentrica* more nearly than the others. Those of the other variety are smaller, more slender, and have a more delicate appearance. They seem to correspond more nearly with the type of *A. mosquensis.* Still, after examining numerous examples from Alaska, British America, Washington Territory, and California, besides some Russian examples of *A. concentrica* and *A. mosquensis*, which I regard as being authentic, in the collections of the Smithsonian Institution, I am of the opinion that all of them represent only one species. Indeed, I am disposed to regard as at most only varieties of one species all the forms which have, from various authors, received the names *Aucella concentrica*, *A. mosquensis*, *A. pallasi*, *A. crassicollis*, *A. piochii*, and *A. erringtonii.* However, it will be convenient, when discussing the *Aucella*-bearing strata of California, to retain the names *A. concentrica* and *A. mosquensis* to indicate the more robust and the more elongate forms, respectively, as they occur in that State.

Before dismissing this reference to *Aucella*, it is well to note how wide is the geographical distribution of the variable form which has been known under the various names which have just been mentioned. This shell was first known in various parts of Russia, and subsequently upon the eastern coast of the Caspian Sea,[29] in Northern Siberia,[30] on the island of Spitzbergen,[31] on Kuhn Island (off the east coast of Greenland),[32] and in Alaska, British Columbia, Washington Territory, and southward to Central California, as mentioned on previous pages of this article. Although it is so variable in certain of its features, so constant is it in its general characteristics and its separateness from related forms that paleontologists are now generally agreed upon its identity in all the widely separated localities which have just been indicated.

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[26] See Geognost. Palaeont. Bemerkungen ueber die Halbinsel Mangischlak und die Aleutischen Inseln, pp. 185–187, Pl. XVII.

[27] See Voyage à la côte Nord-Ouest de l'Amérique, par M. Alph.-L. Pinart, pp. 33–36, Pl. A.

[28] See Bull. U. S. Geol. Survey, No. 4 (1884), pp. 13, 14, Pl. VI.

RELATION OF THE FAUNA OF THE AURIFEROUS SLATES TO THAT OF THE SHASTA GROUP.

The opinion that *Aucella erringtonii* and *A. piochii* Gabb are specifically identical has been formed after having had better advantages for investigating the subject than seem to have been enjoyed by any other person who has written upon the paleontology of California. I have not only examined the original types of those two forms, but hundreds of other specimens of *A. piochii* from Gabb's original and from other localities. Furthermore, I made a personal visit to the locality on the Mariposa Estate where the type specimens of *A. erringtonii* were obtained, and collected better specimens of it from the Auriferous Slates there and in the immediate neighborhood than have before been known. Dr. Becker and his assistant, Mr. H. W. Turner, accompanied me on that visit, when we also obtained from the same slates some fragments of an Ammonite, some impressions of a shell apparently the *Pholadomya orbiculata* of Gabb, others that represent a species of the Pectinidæ, perhaps the *Amusium aurium* of Meek, and still others which are undeterminable. Add to these the *Belemnites pacificus* of Gabb, and we have a fauna of the Auriferous Slates of the Mariposa Estate which amounts to at least five species of mollusks. It is true that only the *Aucella* has been satisfactorily identified as occurring in both the Auriferous Slates[33] and the Shasta Group, but there is nothing in the character of the other four species of mollusks from the Auriferous Slates which would render inconsistent their reference to the age of the Knoxville beds.

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[29] See Eichwald's Geognost. Palaeont. Bemerkungen ueber die Halbinsel Mangischlak und die Aleutischen Inseln, p. 53.

[30] See Middendorf's Reise in den aussersten Norden und Osten Siberiens, erster Band, Theil I, p. 255.

[31] See Lindström, Om Trias-och Juraförsteningar från Spetsbergen. Kongl. Svenska Vetenskaps-Akad. Handlingar, VI, No. 6, p. 14.

[32] See F. Toula, Die zweite deutsche Nordpolarfahrt, II, pp. 497–505; also Quart. Jour. Geol. Soc. Lond., XXXIV (1876), p. 560.

[33] Some of the specimens found in the Auriferous Slates of the Mariposa Estate show more or less distinct radiating lines, and I have observed the same peculiarity among examples from the Knoxville beds, as well as among Russian and Alaskan examples.

The specimens of *Aucella* and other Auriferous Slate species just referred to were obtained by us from the rocks *in situ;* those found near the left bank of the Merced River, Mariposa County, California, about a quarter of a mile below Benton's Mills, being especially satisfactory, as regards both their position in the strata and their condition of preservation. Here the strata have an almost vertical dip, and they are plainly an integral part of the great Auriferous Slate series. A part of our collection, as well as some of those which were collected by King, Gabb, and Miss Errington, were obtained from within a few feet of the famous great quartz vein which traverses the Mariposa Estate, and which is inclosed in the Auriferous Slates.

I did not obtain any specimens of *Belemnites* from the Auriferous Slates, as Gabb and King did, and I have not seen a specimen of Gabb's *B. pacificus*, which he obtained from that formation, but which he did not figure. Judging from his description of that species, it seems probable that it is identical with my subsequently published *B. macritatis*. This last-named form was obtained by Mr. Dall in Alaska, where he found it associated with an abundance of specimens of the shell which I described in the same publication as *Aucella concentrica* var.,[34] and which, as already stated, I regard as identical with both *A. erringtonii* and *A. piochii*.

The great Auriferous Slate series is an immensely thick one, and in Northern California it is known to include strata of Carboniferous age. In Shasta County there is a considerable thickness of strata, apparently a portion of that great series which holds a position below the Carboniferious and between it and the Granite. These strata perhaps represent a still older Paleozoic formation; but no fossils have been found in them. The strata of the great Auriferous Slate series which are actually or presumably referable to Paleozoic age it is not my present purpose to discuss. Indeed, my only object with reference to that great series is to show that at least a part of it is of the same age as the Knoxville beds of the Shasta Group This I think is proved by the identity of *Aucella piochii* and *A. erringtonii*, supported by the general character of the other fossils which the strata of both respectively bear. It is true that this is the only specific identification that has been made; but the species in question is one of extraordinarily wide geographical range, and it is also one of great constancy and exclusiveness as regards its distinguishing characteristics.

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[34] See Bull. U. S. Geol. Survey, No. 4, p. 13, Pl. VI.

THE GEOLOGICAL AGE OF THE AUCELLA-BEARING STRATA OF CALIFORNIA.

Now, as to the true geological age of the *Aucella*-bearing strata of California I think the evidence is not wholly satisfactory. A discussion of this question for the Pacific coast region really involves a discussion of the whole question of the age of the *Aucella*-bearing rocks of Europe, Asia, and North America. In view of my want of personal knowledge of the geology of those distant regions, and the great difference of opinion on this subject among geologists of repute, I am not prepared to discuss the question fully. Still, I am inclined to hold the view which I expressed in Bulletin No. 4, that these California strata and their Alaskan and British Columbian equivalents occupy a position upon the confines of both the Jurassic and the Neocomian. I suspect that the difference of opinion which has been referred to has arisen largely from the equivocal character of the faunas which are associated with *Aucella* in those districts concerning the strata of which the disputes have arisen. Eichwald and Whiteaves both contend that all the strata which bear *Aucella concentrica* and *A. mosquensis* are certainly of Neocomian age. On the other hand, Keyserling, Trautschold, D'Orbigny, and others as confidently assert that they are of Jurassic age; and paleontologists generally have hitherto regarded *Aucella* as an exclusively Jurassic genus. Even so late as the past year, Mr. A. Pavlow, a member of the official geological commission of Russia, has, in a brief publication, placed the well-known strata which in eastern and other parts of Russia bear *Aucella concentrica* in the Jurassic series, as the earlier Russian geologists also did.[35]

I do not think that any satisfactory evidence has yet been presented to show that the genus *Aucella* is exclusively confined to either the Jurassic or the Neocomian, and I know of no reason why we may not expect to find species of it in both Jurassic and Neocomian strata. There seems to me also to be no good reason why *Aucella concentrica* and *A. mosquensis* may not exist in Jurassic strata in Europe and Asia and in the Neocomian in America. It is well known that a considerable number of the Lower Carboniferous species of Europe are found in the Upper Carboniferous of North America; and also that certain species pass from the Devonian to the Carboniferous.

If it shall finally appear that those strata of the Auriferous Slate series which bear *Aucella erringtonii*, together with their equivalents, must be referred to the Neocomian rather than to the Jurassic, the existence of Jurassic strata in California is exceedingly doubtful, because all the other strata in that State which have been referred to the Jurassic are probably equivalent with these.

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[35] See Bull. Soc. Géol. de France, t. XII (sér. 3), June, 1884, pp. 686–696.

CERTAIN CRETACEOUS STRATA WHICH APPARENTLY BELONG BETWEEN THE SHASTA AND CHICO THE GROUP.

Dr. Becker has obtained from strata exposed near the sea-shore at Wallala, Mendocino County, California, a small collection of fossils which are evidently of Cretaceous age, but all the species of which are apparently new, and different from any of those which have been found in either the Chico, or Shasta the Group. They seem to represent a different group of strata from any other fauna of which has yet been published; and as the Rudistæ are usually regarded as characteristic of the median Cretaceous, this small fauna is supposed to belong to a series of strata which intervenes between the Shasta, and Chico the Group. Dr. Becker found no contact between the Chico and these beds, which lie unconformably upon metamorphic rocks, probably of the Knoxville series. The specimens are all in a bad state of preservation, but the following genera have been recognized: *Sphærulites?*, *Ostrea*, *Inoceramus*, *Pecten*, *Cylichna*, *Turritella*, and *Solarium*.

Only two of these species, the *Inoceramus* and *Sphærulites*, appear to be sufficiently characteristic to call for any special remarks. The *Inoceramus* is a very large, subelliptical, subdiscoidal form. The specimens are all much broken, but some of them indicate that the valves sometimes reached nearly a foot in diameter.

It is possible that the form which I have regarded as a species of *Sphærulites* belongs to the genus *Radiolites*, but so far as its generic character can be determined from the crushed and fragmentary specimens, it appears to belong to the former genus. Upon comparing them with some specimens which were sent to the U. S. National Museum by Mr. C. R. Orcutt, from Todos Santos Bay, near San Diego, California, I am quite confident they belong to the same species. The other species which Mr. Orcutt found associated with the San Diego specimens were few, but they are suggestive of certain forms found in the Gosaugebilde of Europe.

REMARKS UPON CERTAIN CALIFORNIA FOSSILS WHICH HAVE BEEN IDENTIFIED WITH EASTERN SPECIES.

Reference has already been made to those species found in California rocks which have been either definitely or provisionally identified with species already known in Cretaceous strata east of the Sierra Nevada. The following is a list of them, together with such remarks as seem to be called for in this connection:

NAUTILUS TEXANUS Shumard.

Dr. Shumard's type specimens of this species were from Texas. He described it in the transactions of the Saint Louis Academy of Science, I, p. 590, but it was never figured by him. Mr. Gabb referred his California specimens only provisionally to *N. texanus*, and also doubtfully to the Shasta Group.[36] After examining specimens from Shumard's original locality which I presume to belong to this species, I think it is not identical with the California form.

AMMONITES PERUVIANUS Von Buch.[37]

Mr. Gabb, with much doubt, referred a fragment which he obtained from the Chico Group of California[38] to the above-named species, as it has been recognized in Texas and the adjacent region. After an examination of Mr. Gabb's specimen, and also several authentic examples of the Texan form, I think Mr. Gabb might have expressed his doubts in even stronger terms.

AMMONITES COMPLEXUS Hall & Meek.[39]

This species was originally described from the Cretaceous No. 4 of Meek & Hayden, at the Great Bend of the Upper Missouri River. Meek afterwards recognize a variety of it among some collections from Vancouver's Island, to which he gave the variety name *suciaensis*.[40] Gabb found a fragment of an Ammonite in the Chico Group of California which he identified with that variety.[41]

There is much reason to doubt whether the Upper Missouri form and that of Vancouver's Island are specifically identical. Also the identification of the Californian and Vancouver's Island forms is not quite satisfactory, although it may be correct.

VOLUTILITHES NAVARROENSIS Shumard.[42]

Shumard's shell was described from Cretaceous strata in Texas which are equivalent with the Ripley Group of Mississippi and Alabama. It has never been figured, and Mr. Gabb's comparisons were made only with Shumard's description.[43] He mentions some differences, and it is probable that others would appear if good and authentic specimens from both the eastern and the western strata could be compared.

TURRITELLA SAFFORDI Gabb.[44]

From the figures given by Gabb in the two publications here cited, it is evident that the eastern and western forms are closely related, and it may be that it will not be practicable to say that they are different.

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[36] See Paleontology of California, I, p. 59, and II, p. 209.

[37] See Marcou's Geology of North America, p. 34, Pl. V. Fig. 1.

[38] See Paleontology of California, I, p. 63.

[39] See Memoirs Am. Acad. Arts and Sciences, V (n. s.), p. 394.

[40] See Proc. Acad. Nat. Sci. Philad. for 1861, p. 317.

[41] See Paleontology of California, I, p. 69, and II, p. 133.

[42] See Proc. Bost. Soc. Nat. Hist., VIII, p. 192.

[43] See Paleontology of California, I, p. 102, Pl. XIX, Fig. 56.

[44] See Paleontology of California, I, p. 135, Pl. XI, Fig. 93; also Jour. Acad. Nat. Sci. Philad. (n. s.), IV, p. 392, Pl. LXVIII, Fig. 12.

TURRITELLA SERIATIM-GRANULATA Roemer.[45]

Mr. Gabb, in his Catalogue of the Cretaceous Fossils of California,[46] records this species, which was originally described from Texas, as among the fossils of the Shasta Group; but he gives neither description nor figure of the California shell.

TURRITELLA UVASANA Conrad.

This is one of the most common and characteristic species of the Téjon Group of California. In Vol. IV, United States Explorations and Surveys West of the One Hundredth Meridian, p. 195, pl. XVIII, figs. 1, *a* and *b*, I identified a shell from the Cretaceous of Southern Utah with this species. I am now satisfied that this reference was not correct, and also that the Utah shell comes from quite a different horizon.

NUCULANA GABBI Conrad.

Gabb originally described and figured this shell from the Cretaceous of New Jersey, under the name of *Leda protexta*.[47] The specific name being a synonym, Conrad changed it to *gabbi*, and placed it under *Nuculana*. Gabb referred a shell from his Martinez and Téjon Groups, in California, to this species.[48] A comparison of Gabb's figures of the two forms (loc. cit.) will, I think, convince any one that they furnish no ground for the opinion that they are specifically identical.

GRYPHÆA VESICULARIS Lamarck.

Of this species Gabb says, in Paleontology of California, Vol. I, p. 205: "A few small specimens of this species were picked up not *in situ*, near San Diego, by Dr. Cooper. It has not been found elsewhere on the west coast."

From the foregoing statements with regard to these fossils, it is plain that the identification which has been made of them is of too doubtful a character to base any generalizations upon it as to the equivalency of any of the California Cretaceous strata with any strata of that period in Central and Eastern North America. Perhaps, with our present limited knowledge of the subject, one would not be fully justified in saying positively that Mr. Gabb was wrong in all these identifications; but the proof of identity is not satisfactory in the case of any of the species. That they are closely similar to the species to which he refers them is true, but satisfactory proof of such identity as would indicate the contemporaneous origin of the strata respectively containing them is certainly wanting.

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[45] See Kreidebildungen von Texas, p. 39, Pl. IV, Fig. 12.

[46] See Paleontology of California, II, p. 227.

[47] See Jour. Acad. Nat. Sci. Philad. (n. s.), IV, p. 303, Pl. XLVIII, Fig. 23.

[48] See Paleontology of California, I, p. 199, Pl. XXVI, Fig. 185; also II, p. 250.

ON THE SEPARATION OF CONTEMPORANEOUS CRETACEOUS FAUNAS IN WESTERN NORTH AMERICA.

Of the various conditions which limit the distribution of marine faunas, the intervention of land-barriers may be regarded as necessarily the most effective, and if such barriers are of great extent they may be well nigh absolute. And yet it is well known that certain fossil as well as living species of marine mollusks have reached an almost world-wide distribution, notwithstanding the intervention of great continental areas. Still, if in the course of the paleontological investigation of any region we find that certain formations in different parts of it which are presumably of the same geological age present a marked difference in the marine molluscan species which each formation respectively contains, it is natural to infer that those faunas, when living, were separated by a land barrier of considerable extent.

The facts which I have observed in Western North America indicate that such a barrier existed during the Mesozoic age in the form of a comparatively narrow continental belt, having a northward and southward trend, which then almost, if not quite, completely separated the respective marine faunas which simultaneously existed upon either side. The former existence of a western continental area, which finally blended with the remainder of the continent, has long been recognized, and I shall not in this connection discuss its existence previous to the Cretaceous period further than to say that there are marked differences between the Carboniferous fauna of California and that of the great continental area to the eastward of the Pacific coast region. At the close of the Knoxville (probably Neocomian) epoch, the western edge of the continental area cannot have been far removed from its present position. At the beginning of the Chico epoch its western boundary was not further westward than the western base of the Sierra Nevada, and at the close of the Lower Cretaceous its eastern boundary was not further eastward than the eastern base of the Rocky Mountain Range in Montana to the northward, and the western base of the Sierra Madre to the southward; that is, the Pacific coast Cretaceous strata now reach to the western base of the Sierra Nevada, while the Missouri Valley Cretaceous reaches as far west as the eastern base of the Rocky Mountains in Montana, and the Texas Cretaceous reaches as far west as the western base of the Sierra Madre in Mexico.

Since the faunas on each side of the site of that belt are distinctly different, although they are presumably of the same age, it seems necessary to infer that the belt was a very long one; otherwise the faunas might easily have become distributed around it. The eastern and western boundaries of the belt were no doubt irregular in trend, and the eastern one especially varied greatly from one epoch to another until all beyond to the eastward became a part of the present continent, The trend of the western coast during the Chico epoch of the later Cretaceous was quite irregular, as shown by the localities at which its fossils have been found. As before intimated, it passed along the western base of the Sierra Nevada; then, sweeping around the northern end of the area which is now occupied by that mountain range, it extended into Eastern Oregon as far as longitude 120°, latitude 44°. This is the most easterly point at which fossils of the Chico Group have been found, and it is much further eastward than any point at which any other of the Pacific coast Cretaceous or of the Téjon deposits have been discovered. It thus appears that while the present site of the Sierra Nevada was within that continental belt during the Chico epoch, the Cascade Range was then either submerged under the Pacific or was broken through by the entrance to a large gulf.

Again, the trend of the western border of that belt did not during the Cretaceous period coincide with the present trend of the Pacific coast to the southward. Such a trend would have thrown the site of the Sierra Madre of Mexico within or to the westward of the continental belt; whereas the existence of eastern Cretaceous deposits upon the western side of that range shows that its place was then in the Cretaceous sea, upon the eastern side of the belt. It is therefore probable that the peninsula of Lower California occupies the site of that portion of the belt which extended southward from the Sierra Nevada.

The bearing of these paleontological data upon the orography of Western North America is obvious; but it is not my present purpose to discuss that question, and I will close these remarks by rehearsing a few facts and indications which I think favor the views which I have advanced as to the extreme length and long continuance of the ancient continental belt of Western North America:

First, the fauna of the Knoxville beds of the Shasta Group extends from Alaska southward at least as far as Central California; second, some fossils which have been sent to the U. S. National Museum from Southern Mexico apparently come from strata of similar age; third, no rocks of the age of that group are known to exist to the eastward of probable site of that belt; fourth, the Jurassic fauna of the strata which lie to the eastward of the assumed site of the belt is entirely different from that of the reputed Jurassic strata to the westward of it.

CONCLUSIONS.

The conclusions which I have reached concerning the questions that are discussed on the foregoing pages may be summed up briefly as follows:

The strata which constitute the Téjon, Martinez, and Chico Groups of Gabb,form one unbroken series, which I have called the Chico-Téjon series, and which rests unconformably upon all the rocks beneath it, and upon which the Miocene rests conformably. The Téjon portion of this series represents the Eocene, and the Chico portion the closing epoch of the Cretaceous. But there is an alternate commingling of types throughout the whole series, so that no horizon can be designated which will sepparate all the Cretaceous types on the one hand and all the Tertiary types on the other. In other words, there is an unbroken faunal and stratigraphical continuity from the Cretaceous to the Tertiary portion of the series.

The Shasta Group is separable into two divisions, which I have designated as the Knoxville beds and the Horsetown beds, respectively. The latter probably represent the age of the Gault of Europe, and the former apparently the age of the Lower Neocomian, or strata upon the confines of the Jurassic. There is probably a hiatus between these two divisions, such as is indicated by the last remark, although a small number of species appear to be common to both.

A small number of species also appear to be common to both the Chico Group and the Horsetown beds of the Shasta Group, although so wide a hiatus is indicated by the types of a large part of their respective fossils, as already mentioned.

The *Aucella erringtonii* of the Auriferous Slates is, with considerable confidence, identified with the *A. piochii* of the Knoxville beds of the Shasta Group. Therefore, those Auriferous Slates are regarded as of the same geological age as the Knoxville beds. It is true that this opinion is reached mainly upon the identification of one fossil species, but that species is one of the most persistent and widely distributed ones in the whole range of the geological series.

The Knoxville beds are regarded as having been synchronously deposited with those widely known *Aucella*-bearing strata which have been found at various points along the northwest coast of North America, and also as homotaxially equivalent with those which in Northern Europe and Asia bear the same species of *Aucella.*

No species of fossils yet found in the California Cretaceous rocks have been satisfactorily identified with any which occur in strata to the eastward of the Sierra Nevada.

This difference in the respective faunas which existed simultaneously at successive epochs is believed to have been due to the presence of a comparatively narrow but long continental belt which existed in the region which now comprises that of the Pacific coast, continuously from a time at least as early as the earliest epoch of the Cretaceous period.

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DEPARTMENT OF THE INTERIOR

BULLETIN

OF THE

UNITED STATES

GEOLOGICAL SURVEY

No. 16

ON THE HIGHER DEVONIAN FAUNAS OF ONTARIO
COUNTY, NEW YORK.

WASHINGTON
GOVERNMENT PRINTING OFFICE
1885

ADVERTISEMENT.

[Bulletin No. 16.]

The publications of the United States Geological Survey are issued in accordance with the statute, approved March 3, 1879, which declares that—

"The publications of the Geological Survey shall consist of the annual report of operations, geological and economic maps illustrating the resources and classification of the lands, and reports upon general and economic geology and paleontology. The annual report of operations of the Geological Survey shall accompany the annual report of the Secretary of the Interior. All special memoirs and reports of said Survey shall be issued in uniform quarto series if deemed necessary by the Director, but otherwise in ordinary octavos. Three thousand copies of each shall be published for scientific exchanges and for sale at the price of publication; and all literary and cartographic materials received in exchange shall be the property of the United States and form a part of the library of the organization: And the money resulting from the sale of such publications shall be covered into the Treasury of the United States."

On July 7, 1882, the following joint resolution, referring to all Government publications, was passed by Congress:

"That whenever any document or report shall be ordered printed by Congress, there shall be printed in addition to the number in each case stated, the 'usual number' (1,900) of copies for binding and distribution among those entitled to receive them."

Under these general laws it will be seen that none of the Survey publications are furnished to it for gratuitous distribution. The 3,000 copies of the Annual Report are distributed through the document rooms of Congress. The 1,900 copies of each of the publications are distributed to the officers of the legislative and executive departments and to stated depositories throughout the United States.

Except, therefore, in those cases where an extra number of any publication is supplied to this office by special resolution of Congress, as has been done in the case of the Second, Third, Fourth, and Fifth Annual Reports, or where a number has been ordered for its use by the Secretary of the Interior, as in the case of Mineral Resources and Dictionary of Altitudes, the Survey has no copies of any of its publications for gratuitous distribution.

ANNUAL REPORTS.

Of the Annual Reports there have been already published:

I. First Annual Report to the Hon. Carl Schurz, by Clarence King. 1880. 8°. 79 pp. 1 map.—A preliminary report describing plan of organization and publications.

II. Report of the Director of the United States Geological Survey for 1880-'81, by J. W. Powell. 1882. 8°. lv, 588 pp. 61 pl. 1 map.

III. Third Annual Report of the United States Geological Survey, 1881-'82, by J. W. Powell. 1883 8°. xviii, 564 pp. 67 pl. and maps.

IV. Fourth Annual Report of the United States Geological Survey, 1882-'83, by J. W. Powell. 1884. 8°. xii, 473 pp. 85 pl. and maps.

The Fifth Annual Report is in press.

MONOGRAPHS.

Of the Monographs, Nos. II, III, IV, V, VI, VII, and VIII are now published, viz:

II. Tertiary History of the Grand Cañon District, with atlas, by Clarence E. Dutton, Capt., U. S. A. 1882. 4°. xiv, 264 pp. 42 pl. and atlas of 24 sheets folio. Price $10.12.

III. Geology of the Comstock Lode and the Washoe District, with atlas, by George F. Becker. 1882. 4°. xv, 422 pp. 7 pl. and atlas of 21 sheets folio. Price $11.

IV. Comstock Mining and Miners, by Eliot Lord. 1883. 4°. xiv, 451 pp. 3 pl. Price $1.50.

V. Copper-bearing Rocks of Lake Superior, by Roland D. Irving. 1883. 4°. xvi, 464 pp. 15 l. 29 pl. Price $1.85.

VI. Contributions to the Knowledge of the Older Mesozoic Flora of Virginia, by Wm. M. Fontaine. 1883. 4°. xi, 144 pp. 54 l. 54 pl. Price $1.05.

VII. Silver-lead Deposits of Eureka, Nevada, by Joseph S. Curtis. 1884. 4°. xiii, 200 pp. 16 pl. Price $1.20.

VIII. Paleontology of the Eureka District, by Charles D. Walcott. 1884. 4°. xiii, 298 pp. 24 l. 24 pl. Price $1.10.

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The following are in press, viz:

IX. Brachiopoda and Lamellibranchiata of the Raritan Clays and Greensand Marls of New Jersey, by Robert P. Whitfield. 1885. 4°. ix, 338 pp. 35 pl.

X. Dinocerata. A Monograph of an Extinct Order of Gigantic Mammals, by Othniel Charles Marsh. 1885. 4°. —, — pp. 56 pl.

XI. Geological History of Lake Lahontan, a Quaternary Lake of Northwestern Nevada, by Israel Cook Russell. 1885. 4°. —, — pp. 46 pl.

The following are in preparation, viz:

I. The Precious Metals, by Clarence King.

Geology and Mining Industry of Leadville, with atlas, by S. F. Emmons.

Geology of the Eureka Mining District, Nevada, with atlas, by Arnold Hague.

Lake Bonneville, by G. K. Gilbert.

Sauropoda, by Prof. O. C. Marsh.

Stegosauria, by Prof. O. C. Marsh.

BULLETINS.

The Bulletins of the Survey will contain such papers relating to the general purpose of its work as do not properly come under the heads of ANNUAL REPORTS or MONOGRAPHS.

Each of these Bulletins will contain but one paper and will be complete in itself. They will, however, be numbered in a continuous series, and will in time be united into volumes of convenient size. To facilitate this each Bulletin will have two paginations, one proper to itself and another which belongs to it as part of the volume.

Of this series of Bulletins Nos. 1 to 16 are already published, viz:

1. On Hypersthene-Andesite and on Triclinic Pyroxene in Augitic Rocks, by Whitman Cross, with a Geological Sketch of Buffalo Peaks, Colorado, by S. F. Emmons. 1883. 8°. 42 pp. 2 pl. Price 10 cents.

2. Gold and Silver Conversion Tables, giving the coining value of Troy ounces of fine metal, etc., by Albert Williams, jr. 1883. 8°. ii, 8 pp. Price 5 cents.

3. On the Fossil Faunas of the Upper Devonian, along the meridian of 76° 30′, from Tompkins County, New York, to Bradford County, Pennsylvania, by Henry S. Williams. 1884. 8°. 36 pp. Price 5 cents.

4. On Mesozoic Fossils, by Charles A. White. 1884. 8°. 36 pp. 9 pl. Price 5 cents.

5. A Dictionary of Altitudes in the United States, compiled by Henry Gannett. 1884. 8°. 325 pp. Price 20 cents.

6. Elevations in the Dominion of Canada, by J. W. Spencer. 1884. 8°. 43 pp. Price 5 cents.

7. Mapoteca Geologica Americana. A catalogue of geological maps of America (North and South), 1752–1881, by Jules Marcou and John Belknap Marcou. 1884. 8°. 184 pp. Price 10 cents.

8. On Secondary Enlargements of Mineral Fragments in Certain Rocks, by R. D. Irving and C. R. Vanhise. 1884. 8°. 56 pp. 6 pl. Price 10 cents.

9. A Report of work done in the Washington Laboratory during the fiscal year 1883–'84. F. W. Clarke, chief chemist; T. M. Chatard, assistant. 1884. 8°. 40 pp. Price 5 cents.

10. On the Cambrian Faunas of North America. Preliminary studies by Charles Doolittle Walcott. 1884. 8°. 74 pp. 10 pl. Price 5 cents.

11. On the Quaternary and Recent Mollusca of the Great Basin; with Descriptions of New Forms, by R. Ellsworth Call; introduced by a sketch of the Quaternary Lakes of the Great Basin, by G. K. Gilbert. 1884. 8°. 66 pp. 6 pl. Price 5 cents.

12. A Crystallographic Study of the Thinolite of Lake Lahontan, by Edward S. Dana. 1884. 8°, 34 pp. 3 pl. Price 5 cents.

13. Boundaries of the United States and of the several States and Territories, by Henry Gannett. 1885. 8°. 135 pp. Price 10 cents.

14. The Electrical and Magnetic Properties of the Iron-Carburets, by Carl Barus and Vincent Strouhal. 1885. 8°. 238 pp. Price 15 cents.

15. On the Mesozoic and Cenozoic Paleontology of California, by Dr. C. A. White. 1885. 8°. 33 pp. Price 5 cents.

16. On the higher Devonian Faunas of Ontario County, New York, by J. M. Clarke. 1885. 8°. 86 pp. 3 pl. Price 5 cents.

Numbers 1 to 6 of the Bulletins form Volume I, and numbers 7 to 14 Volume II. Volume III is not yet complete.

The following are in press, viz:

17. On the Development of Crystallization, etc., by Arnold Hague and J. P. Iddings. 1885. 8°. 44 pp. Price 5 cents.

18. On Marine Eocene, Fresh-water Miocene, and other Fossil Mollusca of Western North America, by Dr. C. A. White. 1885. 8°. — pp. 3 pl. Price — cents.

19. Notes on the Stratigraphy of California, by George F. Becker. 1885. 8°. — pp. Price — cents.

20. Contributions to the Mineralogy of the Rocky Mountains, by Whitman Cross and W. F. Hillebrand. 1885. 8°. — pp. 1 pl. Price — cents.

21. The Lignites of the Great Sioux Reservation, by Bailey Willis. 1885. 8°. — pp. 5 pl. Price — cents.

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STATISTICAL PAPERS.

A fourth series of publications having special reference to the mineral resources of the United States is contemplated.

Of that series the first has been published, viz:

Mineral Resources of the United States, by Albert Williams, jr. 1883. 8°. xvii, 813 pp. Price 50 cents.

The second volume of this series, Mineral Resources 1883 and 1884, is in preparation and will soon be put to press.

Correspondence relating to the publications of the Survey, and all remittances, which must be by POSTAL NOTE or MONEY ORDER, should be addressed

To THE DIRECTOR OF THE
UNITED STATES GEOLOGICAL SURVEY,
Washington, D. C.

WASHINGTON, D. C., *May* 15, 1885.

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UNITED STATES GEOLOGICAL SURVEY
J. W. POWELL DIRECTOR

ON
THE HIGHER DEVONIAN FAUNAS
OF
ONTARIO COUNTY NEW YORK

BY

JOHN M. CLARKE

WASHINGTON
GOVERNMENT PRINTING OFFICE
1885

LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
Washington, D. C., January 13, 1885.

SIR: I have the honor to transmit herewith a paper entitled On the Higher Devonian Faunas of Ontario County, New York, by Mr. J. M. Clarke.

Mr. Clarke has had unusual opportunities for making a critical study of the Devonian strata and faunas of the district mentioned, and I respectfully recommend the publication of his paper in the form of a bulletin as giving valuable new data.

Very respectfully,

CHAS. D. WALCOTT,
Paleontologist.

HON. J. W. POWELL,
Director of the United States Geological Survey.

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THE HIGHER DEVONIAN FAUNAS OF ONTARIO COUNTY, NEW YORK.

By John M. Clarke.

INTRODUCTORY REMARKS.

The materials and the conclusions presented in this paper are the partial results of studies of the Devonian of Western New York, which have been of several years duration. Since the summer of 1877 much attention has been given to the finer subdivision of the Devonian on strictly paleontological evidence, the rich development of Devonian faunas within Ontario County, and in its vicinity, having afforded an unequaled opportunity for such work. What is here given concerns only the Higher Devonian strata and their contents, viz., those of the Genesee, Portage, and Chemung formations, and the materials here made use of have been derived principally from the county of Ontario, with important additions from the eastward and westward extension of these strata into the adjoining counties of Yates and Livingston.

In preparing these notes I have received many kindnesses from my companion in the field, Mr. D. D. Luther, esq., of Naples, N. Y., to whom credit belongs for many of the discoveries here detailed.

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Vol. V, pp. 25–57.

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Journal Acad. Nat. Sci. Phila., Vol. VIII, Pt. II, pp. 228–280.

1842. **Vanuxem, L.**—Geology of New York, Survey Third Geological District.
Pp. 168–185, 249–303.

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Pp. 217-277, 414-449.

1846. **Verneuil, E. de.**—"Note sur le parallélisme des roches des dépôts paléozoiques de l'Amérique Septentrionale avec ceux de l'Europe, suivie d'un tableau des espèces fossiles communes aux deux continents, avec l'indication des étages où elles se rencontrent, et terminée par un examen critique de chacune de ces espèces."
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1858. **Bigsby, J. J.**—"On the Paleozoic Basin of the State of New York, Part I. A synoptical view of the mineralogical and fossil characters of the Paleozoic Basin of the State of New York."
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1858. **Bigsby, J. J.**—The same, Part II. "Classification of the Paleozoic Strata of the State of New York."
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[1] This work is introduced here as it is not altogether a compilation from other works, but contains a number of species not before recognized in these rocks.

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1884. **Ringueberg, E. N. S.**—"A new Dinicthys from the Portage group of Western New York."
In Am. Jour. Sci., 3d ser., Vol. XXVII, pp. 476-478.

THE PETROGRAPHIC AND PALEONTOLOGIC CHARACTERS OF THE GENESEE BEDS.

TYPICAL EXPOSURES.

1. East and west shores of Canandaigua Lake from Seneca Point and Genundewah south to Woodville.
2. The ravines on the west side of Canandaigua Lake, viz.; at Black Point, Seneca Point. and Foster's Point.
3. Cheshire in Canandaigua Township.
4. Bristol Center in "Blacksmith's," Randall's, and other gullies.
5. Hamilton Gully, Honeoye Lake.
6. Glenville, Hemlock Lake.

These shales constitute the uppermost subdivision of the rocks of the Hamilton Period, and are usually regarded as representing the uppermost Middle Devonian in New York. Since the original thorough characterization of these strata in the Geological Report of the Fourth District of New York, in 1843, their petrographical features, in a general sense, have been well known. In Ontario and the adjoining counties they are developed as a mass of bituminous shales, although varying in the amount of organic matter they contain in different horizons and localities.

Bituminous shales occur also in the overlying Naples group of strata, which are separated from the dark layers of the Genesee by a distance of only a few feet of green shales, and on this account their bituminous character does not always serve to identify their outcrops where the adjoining rocks are not exposed. The order of succession in the Genesee strata of the district under consideration is not constant, largely explained by the fact that the rocks are shales, although in the fact of their tendency to local variations these beds differ from the shales of the underlying Hamilton *proprement dit* which I have found to be quite persistent in petrographical character and paleontological contents.

Along the shores of Canandaigua Lake, where the strata have an excellent development, there are at the base of the group about 20 feet of bituminous arenaceous shale, containing rows of concretions of impure calcic carbonate, this overlaid by 40 feet of densely bituminous rock having a perfect cleavage that gives it a close resemblance to a slate. This bed is so rich in organic matters that a blow of the hammer evaporates enough of the lighter hydrocarbons to produce a very strong petroleum smell. Over limited areas it loses its schistose character, becomes compact and densely rich in bituminous matter. The freshly broken surface is of a deep black or dark coffee color, and the streak chocolate brown. On account of numerous planes of jointing which cross these layers, and the capacity of the rock for resisting weathering, they always make a marked feature in a landscape. The exposures are generally high walls covered with projecting battlements, buttresses and parallelopipedons.

Above these strata lies a mass of black, fragile, clay shale, 100 feet thick, which passes into the overlying transition shales.

Further than this there is no variation in the rocks of the Genesee division in Ontario County, except in the case of the thin calcareous beds which are here designated as the *Styliola layer*.

In the summer of 1878 I received from Mr. Hall a small fragment of limestone quite made up of the exuviæ of the little pteropod which had already been described by him as *Tentaculites fissurella*, subsequently as *Styliola fissurella*. The specimen had been collected in the course of the geological survey of 1837–'43 from a loose block in the town of South Bristol, Ontario County. Accompanying the specimen was a request that I should make a search for the outcrop of this rock, and subsequent searches resulted in finding the layer in the midst of the dark shales of the Genesee and about 20 feet from their base, a little to east of the village of Cheshire in the township of Canandaigua. Continued searches for the distribution of the layer have discovered its outcrops in many and widely separated localities throughout the width of the district under consideration. Wherever occurring this layer is quite unique in its composition, consisting almost wholly of the shells of these minute pteropods, which are so small that they measure no more than 1½ to 2^{mm} in length, and so abundant that I have estimated from good specimens of the limestone at least 40,000 individuals to a cubic inch of the rock. *Styliola fissurella* occurs also in great abundance in other horizons, as in the bituminous shales of the Marcellus epoch, where it is very characteristic of the blackest and most fissile layers.[2] Hall has also quoted the species as occurring in great abundance in the Black Slates of Lexington, Indiana, where it is associated with *Chonetes lepida* H. Further on in this paper I note the recurrence of the fossil in great quantities in a concretionary Goniatite-bearing stratum of the Naples shales, but nowhere else does it occur in so great abundance as at this horizon.

This *Styliola layer* varies somewhat in petrographical character in its different outcrops. On the shores of Canandaigua Lake it makes a somewhat concretionary limestone about 1 foot in thickness, and with a strong schistose tendency. In the ravines about Bristol Center and further to the west its concretionary character becomes more strongly marked, and in these places the concretionary masses are overlaid and underlaid by masses of strongly bituminous shale containing the same fossil in the same abundance. Still farther west, in the township of Richmond, and near Hemlock Lake, the layer becomes pretty well separated into a succession of thin, very calcareous bands, which are scattered through a thickness of several feet in the dark shales; but, however it may oscillate between shale and limestone, its place in the rocks is at once marked by the predominance of the *Styliola.* Its persistence is noteworthy, as Mr. Hall states that a similar limestone 6 inches thick is to be found on Cayuga Creek, near Alden, Erie County, about 80 miles further west.

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[2] Paleontology of N. Y., Vol. V, Pt. II, p. 179.

Whether the rock of the stratum be limestone or shale, it is always extremely rich in organic matter. I find that in most of the shales there is quite as great an abundance of *Styliola* shells as in the limestone, while there is a much greater quantity of organic matter, and to this may be ascribed the more perfectly developed tendency to cleavage in the shales, for the calcium carbonate of both limestone and shales is almost wholly derived from these shells. Thin sections show under the microscope that the rock has little else in it than these exuviæ, so closely crowded together that not infrequently one individual is thrust inside of another, and a third inside the second. In whatever direction of a fragment of the rock a thin slice is made, all the interspaces between the individuals which have been longitudinally cut are usually completely filled with transverse sections of other individuals, lying at varying angles to those which have happened to be longitudinally cut. Interstices too small to accommodate a *Styliola* are very often filled with bituminous matter, and it is quite common to find in the interior filling of the *Styliola* a considerable intermixture of organic matter left from the decomposition of the original tenant of the shell. The cementation of these originally loose shells has naturally been effected by percolating waters dissolving and depositing calcic carbonate. The thin sections show that this calcite has been deposited evenly on the entire inner surface of the shells, the youngest surfaces of the deposit coming together in a line, which is the longitudinal axis of the shells, giving thus to the longitudinal section the appearance of vein-infiltration. Many of the longitudinally cut individuals show also an external coating of calcite, which appears at best advantage where the original accumulation of shells has had a somewhat looser texture and plenty of room has thus been left between the shells for the deposition of such a layer. Both external and internal deposits are crystalline. Every *Styliola* shell, whether only filled with calcite or whether it has in addition to its interior filling an external coating of the mineral, shows two distinct sets of what appear at first to be twinning-lines of the rhombohedron $-\frac{1}{2}$ R. Both of these sets of lines take their origin along the central line or axis of the shell, and proceed, each obliquely backward or toward the apex of the shell, through the interior filling, the substance of the shell itself, and the external layer without interruption, and these three layers of calcite show under the polariscope perfect optical and crystalline continuity. Such twinning-lines, as they are ordinarily developed in a crystalline limestone are seen to occur in the individual grains; one series for each grain, but the series in the adjoining grains have absolutely no relation to one another, but in the case of the *Styliola* shells and the accompanying calcite there is always a definite relation between these two sets of twinning-lines; thus the angle which they make with each other is always the same, 49°, and this angle is invariably directed toward the stoma of the shell. Here may be thus an interesting example of the twinning of twinned calcites occurring about these *Styliola* shells. I have noticed, however, that the calcite of the *Styliola* shells invariably, polarizes throughout with the same color, and I have hitherto been unable to detect any difference in the colors afforded by the adjacent lamellæ. Not infrequently is to be discerned in the *Styliolæ* a second, but very indistinct, series of lines making an angle with the lines of the first set, the angle which they make with each other along the axis of the shell being 49° as in the first set, and directed towards the apex of the shell.

The transverse sections of these shells, when made at right angles to the axis show, with crossed Nicols, a radiate-crystalline structure, the radial needles extending from the center through the exterior coating of calcite. Their appearance suggests the structure apparent in a cross-section of a Belemnite, but in the longitudinal sections there is no such evidence of their existence as is found in the Belemnite. In polarized light these transverse sections show very beautifully the dark cross accompanying spherulitic structure. I recently requested of Professor Zirkel, of Leipsic, his opinion of the nature of the double series of lines meeting at the axis in the longitudinal sections of the shell, and have been pleased to learn that he does not regard the lines as lines of twinning, but as lines of cleavage. That these lines have the most evident axial angle always directed toward the stoma of the shell, he regards due to the orientation of the calcite in its deposition, which, under similar circumstances, would be the same for given surfaces. The fact, however, that these rhombohedron cleavage lines have the same relation to the *Styliola* shell and its enveloping calcite as rhombohedron lines to a scalenohedron of calcite, prompts a query whether each one of the acicular shells may not have taken its calcite as a scalenohedron, and whether the *Styliola* shell, itself an acute suggestion of a scalenohedron may not have exercised the influence of a scalenohedron in controlling the subsequent deposition of the calcite. Upon this question the recent investigations of Brongniart,[3] Sorby,[4] and Irving[5] into the character of the induration of ancient sandstones may have an interesting bearing.

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[3] Graines Fossiles. 1880.

[4] Address before Geol. Soc., London. Quar. Jour. Geol. Soc., Vol. XXXVI, p. 62.

[5] Am. Jour. Science, 3d ser., Vol. XXV, No. 50.

The passage from the gray calcareous shales of the Hamilton beds *proprement dit* to the black shales of the Genesee is unusually sharply defined, a fact due evidently to the close proximity of the Tully limestone (the limit between the Hamilton and Genesee, wherever it appears). This formation is lacking in New York west of the village of Bethel, in the township of Gorham, but for a distance of 10 or 15 miles west of its last appearance its influence seems marked by the clearly defined separation between the shales of the Genesee and those of the underlying Hamilton.

But with this plane of separation very clearly marked I notice three species of brachiopoda which belong strictly to the Hamilton epoch fauna, and which cannot be regarded as an element in the proper fauna of the Genesee epoch, passing a short distance from the upper limit of the Hamilton shales into the black shales. These are *Spirifera medialis*, var. *Eatoni* H.; *S. Tullia* H.; *Orthis idonea* H.

Leaving these three fossils out of consideration, it will be seen from the table appended at the close of the discussion of the fauna of the Portage group, that there are nine species common to the faunas of the Hamilton and the Genesee epochs in this district, and it is true that with the exception of the species *Chonetes lepida* and *Chonetes setigera* none of them are in any sense characteristic or abundant in the Hamilton.

REVIEW OF THE FAUNA AND FLORA OF THE GENESEE SHALES.

PISCES.

Genus POLYGNATHUS.

1. Polygnathus dubius.

Polygnathus dubius Hinde, G. J., Quar. Jour. Geol. Soc., Vol. XXXV, p. 362, Pl. XVI, Figs. 6–18.

This "Conodont" tooth agrees well with some of the variations of the above species. It is the only species which I have noticed in this horizon. From the upper shales of the group at Glenville, Hemlock Lake. (*Vide* description of fossils of the Naples Shales for more particulars in regard to the occurrence of these fossils.)

Genus DINICTHYS.

2. Dinicthys Newberryi, n. sp.

(Plate I, Fig. 1.)

From the concretions in the black, bituminous, so called Huron Shale of Ohio, which is probably closely equivalent in age with the Genesee and Naples shales of New York, Newberry described, in 1873,[6] the above mentioned genus with two species. These two forms have introduced to our knowledge a novel sort of monstrous fishes, and the species *D. Terrelli* and *D. Hertzeri* have gained a well-deserved reputation on account of their immense size, formidable appearance, and peculiar zoölogical relations, as well as for the beauty of the specimens obtained.

Kayser has described (Zeitsch. d. deutsch. Geol. Gesell. Vol. XXXII, p. 817) a third species under the name *Dinicthys* (?) *Eifelensis*, from Gerolstein.

From the concretions of the *Styliola layer* in Blacksmith Gully, at Bristol Center, I have a beautifully preserved specimen of the lower right mandible, with the right maxillary and portions of the cranial bones of an individual of this genus. The lower mandible, which is the best preserved of all of the parts taken, is just about one-half the size of the corresponding part of either of the Ohio species. In the possession of a sharp, even, knife-like cutting edge on the mandible instead of a finely-toothed cutting edge, it is more closely allied to *D. Terrelli* than to *D. Hertzeri*, but the jaw in its relative dimensions is much less stout than in *D. Terrelli*, approaching in these particulars much more closely to *D. Hertzeri*. To show these relative proportions clearly I give herewith the measurements in the two previously described species of what may be regarded the constants in the right lower mandible for comparison with those in this smaller form. In the diagrams, column A gives the length of the mandible; B, its width at a point half way from the posterior angle to the cutting edge; C, the width from the anterior end of the cutting edge to the base of the mandible; D, from the apex of the anterior prehensile tooth to its base.

	A.	B.	C.	D.
	cm.	*cm.*	*cm.*	*cm.*
D. Terrelli	56¼	15	13¾	21½
D. Hertzeri	59	13⅛	11⅛	17 13/16
D. Newberryi	28⅛	6¼	5¼	8¼

By reducing these dimensions to the standard of the smallest species, we have these ratios:

	A.	B.	C.	D.
D. Terrelli	2	2.4	2.6	2.5
D. Hertzeri	2.1	2.1	2.1	2.1
D. Newberryi	1	1	1	1

This mandible thus is not quite one-half the size of that of either of Dr. Newberry's species, but in its relative proportions it agrees quite closely with those of *D. Hertzeri*, while *D. Terrelli*, having a greater width in proportion to its length, has a stouter jaw. In the right maxillary we have these measurements to compare with the like in *D. Terrelli.* (I have not been able to ascertain them for *D. Hertzeri.*)

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[6] Geological Survey of Ohio., Pal., Vols. I and II.

	Length.	Width.
	cm.	*cm.*
D. Terrelli	15⅝	8½
D. Newberryi	6¼	3¾

Their ratio will be:

D. Terrelli	2.5	2.3
D. Newberryi	1	1

There is thus a similar disproportion in these bones to that in the mandibles of the two species. This measurement of width for the maxillary of *D. Terrelli* does not include the triangular process on its upper posterior limb, which is wanting in *D. Newberryi.*

In the same *Styliola layer* as it outcrops on the east side of Canandaigua Lake, near Genundewah, 6 miles from the Bristol locality, I had earlier discovered a dorso-median plate belonging presumably to the same species. Its dimensions are as follows: Length, 12½^{cm} (broken); width, anteriorly, 13¾^{cm}; height of carinal process, 5^{cm}.

In the Ohio species these dimensions are in centimeters:

D. Terrelli, 65 : 57½ : 10.
D. Hertzeri, 67½ : 53 : 10.

Compared with *D. Newberryi*, their ratios are:

D. Terrelli, 5.2 : 4.2 : 2.
D. Hertzeri, 5.4 : 4 : 2.
D. Newberryi, (?) 1 : 1 : 1.

The posterior edge of this plate in *D. Newberryi* is broken and has apparently lost 3 or 4^{cm} from its length. The smallness of the bones of *D. Newberryi* does not indicate immature growth of an individual of either of the other species. The discovery in outcrops of the same horizon, in localities separated by a distance of several miles, of bones of different individuals, all of which seem to agree with one another in their relative proportions, is at least presumptive evidence that these individuals had attained maturity and that the size of the bones given above is that of normal full growth. (Since writing the above I have received the description of A new Dinicthys from the Portage Group of Western New York, by E. N. S. Ringueberg (Am. Jour. Sci., 3d ser., Vol. XXVII, No. 162, June, 1884, p. 476.)

Mr. Ringueberg's species is from Sturgeon Point, on Lake Erie, 20 miles below Buffalo, and was found in the black shales of the Portage Group, the specimen consisting of a somewhat fragmentary dorsomedian plate. This plate agrees well, in general dimensions, with that of *D. Newberryi*, but there is nothing in the latter like the strongly bifurcate crest represented by Mr. Ringueberg, and the species must be regarded as distinct.

Genus PALEONISCUS.

3. Paleoniscus devonicus, n. sp.

(Plate I, Figs. 2-6.)

(The description of this species is given with the notice of the fauna of the Naples Shales.)

A single scale of this species I have found in the shales of Glenville, Hemlock Lake, a few feet above the *Styliola layer.*

CRUSTACEA.

Genus CERATIOCARIS.

4. Ceratiocaris longicaudus.

Ceratiocaris longicaudus Hall, Sixteenth Ann. Rep. N. Y. State Cab. Nat. Hist., 1863.

The telson spines of this species occur in the concretions of the upper arenaceous layers at Whale's Back, on Canandaigua Lake.

CEPHALOPODA.

Genus GONIATITES.

5. Goniatites complanatus.

Goniatites complanatus Hall, Geol. N. Y., Survey Fourth Geol. Dist.

To be found occasionally in the more arenaceous layers.

6. Goniatites discoideus.

Goniatites discoideus Hall, Thirteenth Ann. Rep. N. Y. State Cab. Nat. Hist., 1860.

This species, which has usually been regarded as characteristic of the Marcellus shales, occurs in fine examples in the *Styliola layer.*

7. Goniatites Patersoni.

Goniatites Patersoni Hall, Pal. N. Y., Vol. V, Pt. II, 1879.

The concretionary portions of the *Styliola layer* on Canandaigua Lake have afforded evidence of the comparative abundance of this species, which has been hitherto regarded as diagnostic of the Portage Group.

8. Goniatites nodifer n. sp.

Shell umbilicate, body-whorl expanding rapidly outwards, its width at the stoma being 2½ times that at the beginning of the volution, compressed laterally, sloping gradually to the dorsum which is rounded, widest on the inner margin where it falls away abruptly to the inner whorls. The umbilicus shows five whorls which overlap one another in such a way as to leave each preceding one exposed for about one-fifth its width. Diameter of the normal full grown shell 14^{mm}, of which the the umbilicus covers 5^{mm}. *Suture:* Dorsal lobe short, lanceolate; dorsal saddles small, rounded and sloping slightly toward the umbilicus, outer lateral lobes somewhat narrower than the dorsal saddles but of the same length; lateral saddles broad, rounded, twice as long as dorsal saddles, and distinctly sloping toward the umbilicus. Inner lateral lobe short, rounded and ventral saddle small and indistinct. This suture is very similar to that of *G. planorbis* Sandb. (Versteinerungen d. Rhein. Schicht. Nass., p. 96, Pl. IX, Fig. 3), though the Nassau species is a much more umbilicate shell. The inner whorls are edged with strong nodes, which may be the protruding ends of ridges passing across the whorls. These number from 12 to 16 for each whorl, but become fainter on the younger whorls, and are hardly distinguishable on the last volution. No other marks of ornamentation are visible.

This species is a rare form occurring in the *Styliola layer* in association with *G. Patersoni* H., and as one of the Crenate goniatites stands in close sutural relations to this fossil. Its nearer allies, however, both in form, suture, and strength of umbilication, are *G. planorbis* Sandb., *G. lamellosus* Sandb., and *G. tuberculosus* d'Arch. and Verneuil.

From Genundewah, Canandaigua Lake.

It is a matter of regret to me that on account of the recent discovery of this species it has been inconvenient to prepare an illustration of it.

Genus ORTHOCERAS.

9. Orthoceras pacator.

Orthoceras pacator Hall, Pal. N. Y., Vol. V, Pt. II, 1879.

A single finely-preserved example from the *Styliola layer* is referred to this species, which has hitherto been regarded as confined to the shales of the Portage Group.

Genus GOMPHOCERAS.

10. Gomphoceras manes.

Gomphoceras Manes Hall, Pal. N. Y., Vol. V. Pt. II, 1879.

A large fragment measuring 3 inches in diameter, probably belongs to this species. From the *Styliola layer.*

PTEROPODA.

Genus COLEOLUS.

11. Coleolus aciculum.

Orthoceras aciculum Hall, Geol. N. Y., Survey Fourth Geol. Dist., 1843.
Coleolus aciculum Hall, Pal. N. Y., Vol. V, Pt. II, 1879.

Occasionally in the lower arenaceous shales on Canandaigua Lake, and not uncommon in the *Styliola layer.*

Genus TENTACULITES.

12. Tentaculites gracilistriatus.

Tentaculites gracilistriatus Hall, Pal. N. Y., Vol. V, Pt. II, 1879.

Not infrequent; associated with the following species in the calcareous layers.

Genus STYLIOLA.

13. Styliola fissurella.

Tentaculites fissurella Hall, Geol. N. Y., Survey Fourth Geol. Dist., 1879.
Styliola fissurella Hall, Pal. N. Y., Vol. V, Pt. II, 1879.

Rare, except in the calcareous layers and concretions.

GASTROPODA.

Genus PLEUROTOMARIA.

14. Pleurotomaria Itys var. tenuispira.

Pleurotomaria Itys var. *tenuispira* Hall, Pal. N. Y., Vol. V, Pt. II, 1879, Pl. XXX, F. 25.

The concretions of the *Styliola layer* afford in considerable abundance a species of Pleurotomaria agreeing with this variety in its strong revolving striæ, which are especially prominent on the upper surface of the whorls.

The original of Hall is from the Hamilton Shales of Hamburgh, N. Y.

15. Pleurotomaria rugulata.

Pleurotomaria rugulata Hall, Thirteenth Ann. Rep. N. Y. State Cab. Nat. Hist., 1860.

This species, which is very characteristic of the Marcellus shales, I have found in a few instances in the lower shales in Bristol Center.

Genus BELLEROPHON.

16. Bellerophon striatus (?).

Bellerophon striatus Ferussac and d'Orbigny. Bronn, Lethæa Geognostica, Pl. I, Fig. 11.

The concretions of the *Styliola layer* contain a Bellerophon, which will probably be referable to this species. This shell has a width of from 16 to 18^{mm} across the stoma, is not explanate, but has the proper proportions of *B. striatus* as given in the place cited. The younger portion of the body whorl is covered by a callous, the remainder of the volution showing an ornamentation consisting of tubercles or papillate elevations, crossing which may be seen the lamellose lines of growth. The dorsum is strongly defined, is free of tubercles, and is crossed by retrally bent lines of growth. *B. Mœra* H. (Pal. N. Y., Vol. V, Pt. II, p. 119, Pl. XXV, Figs. 9–14, and Pl. XXVI, Figs. 19–24) has a similarly tubercled surface, but the dorsum is also tubercled.

From Genundewah, Canandaigua Lake.

Bellerophon striatus occurs in rocks of approximately the same age, in the Iberg formation of the Harz Mountains.

PELECYPODA.

Genus LUNULICARDIUM.

17. Lunulicardium fragile.

Avicula fragilis Hall, Geol. N. Y., Survey Fourth Geol. Dist., 1843.
Lunulicardium fragile Hall, Pal. N. Y., Vol. V, Pt. I, 1883.

Very abundant in the *Styliola layer* on Canandaigua Lake in very large and finely preserved examples. Very common also in the more sandy shales of the series, generally in a flattened condition.

Genus CARDIOLA.

18. Cardiola retrostriata.

(For the synonymy and further discussion of this species see remarks on the fauna of the Naples shales.)

This species, which reaches its culmination in the overlying Naples shales, occurs sparingly in the transition beds at the top and the arenaceous shales at the base of the Genesee.

BRACHIOPODA.

Genus LEIORHYNCHUS.

19. Leiorhynchus quadricostatus.

Orthis quadricostata Vanuxem, Geol. N. Y., Survey Third Geol. Dist., 1842.
Atrypa quadricostata Hall, Geol. N. Y., Survey Fourth Geol. Dist., 1843.
Rhynchonella quadricostata Hall, Tenth Ann. Rep. N. Y. State Cab. Nat. Hist., 1857.
Leiorhynchus quadricostatus Hall, Thirteenth Ann. Rep. N. Y. State Cab. Nat. Hist., 1860.

Not an uncommon species; associated with *Discina Lodensis* in the more bituminous layers.

Genus CHONETES.

20. Chonetes lepida.

Chonetes lepida Hall, Tenth Ann. Rep. N. Y. State Cab. Nat. Hist., 1857.

Characteristic of the Marcellus shales, and occurring but sparsely at this horizon.

21. Chonetes setigera.

Strophomena setigera Hall, Geol. N. Y., Survey Fourth Geol. Dist., 1843.
Chonetes setigera Hall, Tenth Ann. Rep. N. Y. State Cab. Nat. Hist., 1857.

Not common; much more abundant in the Hamilton shales below and the Chemung group above. From the *Styliola layer.*

Genus DISCINA.

22. Discina Lodensis.

Orbicula Lodensis Vanuxem, Geol. N. Y., Survey Third Geol. Dist., 1842.
Discina Lodensis Hall, Pal. N. Y., Vol. IV, 1867.

Quite abundant in the higher, more bituminous strata at Seneca Point, on Canandaigua Lake, at Bristol Center, and at Glenville, on Hemlock Lake.

Genus LINGULA.

23. Lingula spatulata.

Lingula spatulata Vanuxem, Geol. New York, Survey Third Geol. Dist., 1842.

Extremely abundant in the *Styliola layer* in all its outcrops, passing through noticeable variation in size.

Genus CLADOCHONUS.

24. Cladochonus sp.

A member of this genus, whose specific relations have not been determined, occurs with some frequency in the *Styliola layer* on Canandaigua Lake.

CRINOIDEA.

Genus MELOCRINUS.

25. Melocrinus Clarkei.

Melocrinus Clarkei H. S. Williams, Proc. Acad. Nat. Sci., Phila., p. 31, 1882.

This species, which is the only crinoid described from the Genesee rocks, is limited, as far as my knowledge of it goes, to a very well defined horizon. The first specimens, consisting of a slab with eight individuals in a fine state of preservation, were found twelve years ago in Bell's Gully, on Canandaigua Lake, and until the summer of 1881 all efforts to find further traces of the species in the Genesee had been in vain. In that summer a single calyx was obtained from a thin calcareous layer about 10 feet above the *Styliola layer* near Seneca Point, on Canandaigua Lake, and subsequently discovered at the same distance above the *Styliola layer* in Bristol Center an exposure which showed seventeen calices in good preservation. This layer, which seems to be persistent over an area at least of some miles square, is not over an inch in thickness, and indicates that although this crinoid had encroached, apparently in great numbers, upon the bottom of the retired, quiet sea of this epoch so rich in decomposing organic matter, in a place where its environment would seem to be entirely against its successful growth, the entire plantation was soon overwhelmed, and the species did not return until the appearance of the fauna of the Naples shales.

PLANTÆ.

Genus LEPIDODENDRON.

26. Lepidodendron primævum.

Lepidodendron primævum Rogers, Geol. Survey, Penn., Vol. II, 1858.

This species is rarer at this horizon than in the fauna of the Naples shales, but is occasionally to be found in the *Styliola layer*, and in the bituminous strata at Black Point, Canandaigua Lake.

27. Lepidodendron Gaspianum.

Lepidodendron gaspianum Dawson, Quar. Jour. Geol. Soc., Vol. XVIII, 1862.

I have no knowledge of the previous identification of this species in the rocks below the Chemung group. Dr. Dawson has identified it from the *Styliola layer*.

Genus CALAMITES.

28. Calamites inornatus.

Calamites inornatus Dawson, Quar. Jour. Geol. Soc., Vol. XVIII, 1862.

A single specimen of this species, 13 inches long and 3 inches wide, agrees well in its coarse, broad flutings with the original description of the species. From the very bituminous shales at Black Point, Canandaigua Lake.

Genus CLADOXYLON.

29. Cladoxylon mirabile.

Cladoxylon mirabile Unger, Beitrag z. Paläontologie d. Thüringer Waldes, 1856, p. 93, Pl. XII, Figs. 6, 7.

This species has been identified by Dawson (Fossil Plants of the Erian and Silurian of Canada, Pt. II, 1882, p. 126) from specimens taken from the *Styliola layer* on Canandaigua Lake. This is its first identification in America, the original having been described from the Upper Devonian at Saalfeld.

Genus CYCLOSTIGMA.

30. Cyclostigma affine.

Cyclostigma affine Dawson, Quar. Jour. Geol. Soc., Vol. XXXVII, 1881, p. 279, Pl. XII, Figs. 11, 12.

This species, described from specimens taken in the adjoining county of Yates, has been recognized by Dr. Dawson, also, in the *Styliola layer* of Canandaigua Lake.

Genus DADOXYLON.

31. Dadoxylon Clarkei.

Dadoxylon Clarkei Dawson, Fossil Plants of the Erian and Upper Silurian Formations of Canada, 1882, Pt. II, p. 124.

Described from examples from the *Styliola layer*. The specimens from which the original description has been made were comparatively small branches, measuring but an inch or two in diameter. More recently I have found examples 5 inches in diameter and nearly 3 feet in length. The abundance of this species in the *Styliola* horizon, and especially in the large concretions in the shales immediately overlying, is very worthy of note. I have found it in every outcrop of the *Styliola layer* known to me, and at Bristol Center it occurs in great quantity and with fine preservation. It has proved itself the most abundant fossil wood of the Devonian of this district. To account for its presence we may assume the close proximity of land, perhaps wooded islands, as suggested by Dawson, or the mouth of some large continental water-course, through whose agency this drift-wood was carried out to sea. Its constant association, however, with the pelagic fossil *Styliola* leads us to believe that either it must have been carried in large quantities far out to sea, or that the little pteropods were swept in by ocean currents from deep water. The latter may be more probable, inasmuch as the character of the fauna and flora as a whole, with the lithological features of the formation, are such as to indicate a quiet, protected, and moderately shallow sea. The occurrence of the one crinoid known in the group, *Melocrinus*, has a definite bearing upon this conclusion. As far as known it appeared but at one horizon in the Genesee, and then in great numbers; migrating from its proper environment in deep waters, it encroached upon the Genesee fauna, but was soon overwhelmed by a deposit of muddy sediment, and did not appear again until toward the close of the epoch in which the Naples shales were laid down.

Genus SPORANGITES.

32. Sporangites Huronensis.

Sporangites Huronensis Dawson, Am. Jour. Sci., 1871, p. 257.

Specimens of these spores I have found in places in the more bituminous portions of the Genesee shales, but they are not commonly well preserved. It has been suggested by various authorities, most lately by Orton[7] for the Ohio Devonian and Subcarboniferous bituminous shales, that the bituminous matter contained in these rocks may be due in a large measure to these lycopodiaceous spores, from the permeation of the resinous matter contained by them through the containing rock. Whether or not this is the case, I have found these or similar macrospores in the Corniferous limestone in much greater abundance and in a more perfect state of preservation than in the Genesee, in a rock which is not black and can hardly be called bituminous. Dawson[8] has recently described from the Devonian beds of Rio Trombetos and Rio Curuá, Brazil, forms of spore-sacs which he has regarded as closely allied to the modern Rhizocarps represented by the genus *Salvinia*, and for these he has suggested the generic name *Protosalvinia*. The macrospores contained in these sporocarps are in all respects similar to the scattered macrospores of the Genesee and Corniferous. Evidence of enveloping membranes or sporocarps, for these North American[9] spores, such as are found in the Brazilian species, is not yet at hand, but in view of the similarity existing in the macrospores themselves of these different North and South American species, Dawson suggests the probability that all of these Devonian Sporangites were allied to the modern Rhizocarps.

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[7] Source of Bituminous Matter in Ohio Black Shales, Am. Jour. Sci., 1882, p. 171.

[8] On Rhizocarps in the Paleozoic Period, Proc. Am. Ass. Adv. Sci., Vol. XXXII, 1883.

In addition to these species, which constitute the known fauna and flora of the Genesee rocks of Ontario County, others have been described by other investigators from the outcrops of these rocks in other portions of the State. Hinde[10] has described a large number of species of "Conodonts" from the Hamilton and Genesee shales of North Evans, Erie County, of which the following, in addition to the one I have already mentioned, are quoted from the Genesee:

Prioniodus angulatus.
acicularis.
armatus.
spicatus.
Polygnathus nasutus.
princeps
palmatres.
punctatus.

The following species is quoted by Vanuxem:[11]

Lingula concentrica Vanuxem.

By Hall:[12]

Discina truncata Hall.

By Williams:[13]

Ambocœlia umbonata Conrad.

By Dawson:[14]

Rachiopteris pinnata Dawson.

The Pyrite Fauna.—In the more fissile bituminous strata of the Genesee, occurring in both the lower and the higher layers, there are very often to be found nodules or concretions of pyrite, usually somewhat kidney-shaped, or a little flattened from lying in the shale, often made up of masses of cubic or pyritohedral crystals and not infrequently as large as one's head. To find fossils preserved in pyrite is a very common occurrence in all the Devonian strata of New York, as it is indeed in the strata of nearly every age. But these pyrite nodules of the Genesee prove to contain a fauna almost entirely of their own, and though it is an association of fossils quite in consonance with its Devonian surroundings, all the species which I have hitherto found them to contain are to be found nowhere else.[15]

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[9] *Vide* for later investigations of these spores, Am. Jour. Sci., Vol. XXIX, April, 1885, pp. 284-289.

[10] Quar. Jour. Geo. Soc., Vol. XXXV, 1879.

[11] Geol. N. Y., Survey Third Geol. Dist., 1842.

[12] Geol. N. Y., Survey Fourth Geol. Dist., 1843; Pal. N. Y., Vol. IV, 1867.

[13] Pal. Researches, "Science," Vol. I, No. 16, 1880.

[14] Quar. Jour. Geol. Soc., Vol. XVIII, 1862.

[15] With the exception of *Chonetes lepida* H.

I describe herewith the species I have determined, and take pains to give them names suggested by their environment, which will serve to keep them distinct as a fauna. I believe there is abundant opportunity to enlarge this fauna, and I trust this suggestion may be of value to others studying the same rocks.

Genus BEYRICHIA.

33. **Beyrichia Dagon**, n. sp.

(Plate II, Figs. 6, 7.)

This species measures $\frac{3}{4}^{\mathrm{mm}}$ in length and $\frac{3}{8}^{\mathrm{mm}}$ in its greatest width, which is posteriorly. Hinge line straight; ventral outline semi-oval, rounding somewhat abruptly on the posterior margin, bounded by a well-marked rim on both valves. Posterior third of the shell broadly tumescent, anterior extremity less so. Medially on the dorsal margin is a prominent tubercle, extending one-half the way across each valve. Surface smooth. From Bristol Center.

Genus GONIATITES.

34. **Goniatites Astarte**, n. sp.

(Plate II, Figs. 9, 10.)

Width, $1\frac{1}{2}^{\mathrm{mm}}$; thickness, 1^{mm}. The remarkable rotundity which this relatively great thickness gives to the shell gives it a peculiar form which is not represented elsewhere in the Devonian of New York. Volutions, two or three. Widely umbilicated. Septa simple, arising from the ventral suture with a low, backward curve, bending very gradually forward to a long, slightly rounded dorso-lateral saddle, and turning thence abruptly to a sharp angular dorsal lobe. Ten or twelve septa in the first volution. Whorls depressed. Surface as far as known, smooth. This is quite an abundant form in the Bristol pyrite nodules.

Genus ORTHOCERAS.

35. **Orthoceras Stebos**, n. sp.

(Plate II, Fig. 15.)

I have but a single individual of this species, which measures $2\frac{1}{2}^{\mathrm{mm}}$ in length and $\frac{3}{4}^{\mathrm{mm}}$ in width. Surface marked by strong, evenly rounded annulated elevations, which are not always the same distance apart. These annulations and the interspaces are covered with extremely minute transverse linings, equally strong on both elevations and depressions. The shell widens somewhat abruptly at the body chamber. Septa not known.

36. **Orthoceras Mephisto**, n. sp.

(Plate III, Fig. 2.)

Shell measuring 3^{mm} in length and showing the body-chamber and eight air chambers. Shell smooth and evenly tapering from the body-chamber. Septa at equal intervals. This is quite the commonest Orthoceras in the nodules and in its proportions suggest the Hamilton species, *O. exile* H.

37. Orthoceras Asmodeus, n. sp.

(Plate III, Fig. 3.)

Length 1^{mm}. A beautiful little species, presenting a form quite different from any other known Devonian Orthoceras in its relatively strong and evenly rounded annulations, which are marked by the finest longitudinal striations. No trace of septa visible.

Genus PLATYOSTOMA.

38. Platyostoma Belial, n. sp.

Width of shell across the body whorl less than 1^{mm}. Very depressed, three volutions visible. Body whorl large, flattened, and subangulated. Aperture triangular. This minute shell is quite abundant at Bristol, and elsewhere, but so small that the drawings made of it have not been successful enough to justify publishing.

Genus LOXONEMA.

39. Loxonema (?) Moloch, n. sp.

This shell is much rarer than the foregoing; measures 3^{mm} in length, 1^{mm} in width across the body whorl. Whorls three or four. Its generic characters are not certain, as the forms thus far met with are internal casts.

Genus MODIOMORPHA.

40. Modiomorpha (?) Chemos, n. sp.

Length, 2^{mm}; width, $1\frac{1}{2}^{mm}$. Beaks anterior, elevated over the hinge line, and apices appressed; anterior ligament pit short, posterior long, reaching nearly to posterior extremity of the shell. Surface marked by low, concentric ridges of growth.

Genus SPIRIFERA.

41. Spirifera Belphegor, n. sp.

(Plate III, Fig. 13.)

Ventral valve measures 6^{mm} in its greatest width and $4\frac{1}{2}^{mm}$ from apex to anterior margin. Beak prominent, arched and incurved over the cardinal area. Hinge line $1\frac{1}{2}^{mm}$ long, or one-fourth the width of the shell. From the extremities of the hinge line the margins round gradually to the lateral extremities. The surface marked by 14-16 very distinct plications, the strongest of which run almost to the apex. Medial sinus broad, measuring $1\frac{1}{2}^{mm}$ on the anterior margin. The cast shows that the cardinal processes are long, extending one-third the length of the shell, and are subparallel. Dorsal valve elevated along medial fold, depressed on the lateral portions, with 10–12 elevated, radiating plications. Beak slightly elevated and closely incurved. I have only interior casts of these shells, the surface of which shows characteristic markings, which were probably also the markings of the exterior of the original test, as, wherever in any of these fossils from the pyrite the test has been preserved, it is seen to be extremely thin and delicate. Both valves are marked with the finest radiating lines, which are equally strong on the plications and sinuses. This species is the largest from these pyrite nodules, and is not common. The figure shows the ventral valve ten times enlarged, but I have not been able to obtain a satisfactory drawing of the dorsal valve.

42. **Spirifera Pluto**, n. sp.

(Plate III, Fig. 12.)

This is quite an abundant species, which differs from the foregoing in size and in several surface features. The ventral valve measures 3½$^{\mathrm{mm}}$ in diameter and 2½$^{\mathrm{mm}}$ from apex to anterior margin. Beak slightly arched and incurved, and the slope to the anterior margin is very gradual. Medial sinus wide, angled at the bottom and smooth, on each side being eight or nine slightly angulated plications. Cardinal area low and short, and evenly rounding on the extremities to the anterior margin. Cardinal processes long, slightly diverging, between which lies a short mesial process. Dorsal valve somewhat flatter, with a low medial fold and 5–7 radiating plications on either side of it. The surface of the shell shows no ornamentation. These shells will be discriminated from the foregoing species by their size, which varies but little.

Genus LEIORHYNCHUS.

43. **Leiorhynchus** (?) **Hecate**, n. sp.

(Plate III, Fig. 14.)

I refer to this genus the most abundant of these fossils. The shell is orbicular; width, 2$^{\mathrm{mm}}$. Ventral valve marked with a broad central depression running from beak to anterior margin, the bottom of which is somewhat flattened and divided into two low ridges by a central shallow sulcus. On either side of the depression are to be counted five rounded plications, which become obsolete before reaching the beak. Beak elevated, ventricose, and arched over the hinge line. Area high. Dorsal valve more depressed, with a corresponding number of plications; beak depressed. On the ventral valve, cardinal processes prominent, diverging. On dorsal valve mesial process discernible. Surface free of sculpture.

Genus CHONETES.

Chonetes lepida.

Chonetes lepida Hall.

I have one specimen of this species from Bristol Center, the only previously described species, to my knowledge, occurring in these concretions. This specimen measures 5^{mm} wide and $3\frac{1}{2}^{mm}$ long, which is about the normal size of the shell as it occurs in the Marcellus shales.

Here is, thus, a fauna which is entirely in harmony with the character of the fauna of the Hamilton group, and yet entirely discordant with the fauna of the Genesee rocks which contain it. The question of its origin and the nature of the sea in which it flourished, the reasons for its occurrence only with the pyrite segregations, and the possible effects of its environment upon it, are not easily to be determined. The extreme minuteness of the fossils enhances rather than lessens the interest attaching to them. The inclination which I had at first to regard them as only young, immature individuals of known species, was soon overcome by the thought that there are no fossils known in the group which could serve as adult forms to such embryos. On account of similarities in some features with species of the Hamilton shales, as those existing between *Spirifera Belphegor* and *S. Clintoni* H.; *S. Pluto* and *S. Tullia* H.; *Orthoceras Mephisto* and *O. exile* H.; *O. Stebos* and *O. Thoas* H. and *O. nuntium* H. There is also a temptation to assume that the fauna is an abnormal and aborted survival of the fauna of those shales. It may be very probable that such was the origin of this fauna, but in assuming that the species have been in any degree aborted by their peculiar environment, it is necessary to bear in mind the coexistence of *Chonetes lepida* in its normal full size. The nodules of pyrite containing the fossils are not infrequently quite isolated, and yet where they have been found to be most abundant, namely, in the gullies at Bristol Center, they occur in such a manner that though they are generally quite disconnected from one another, they can be traced for some distance lying in the same horizon and at perhaps a distance of a foot or two above or below a similar layer. In some instances the pyrite may be seen extending for a distance of several feet as a continuous lenticular mass an inch in thickness.

These masses and nodules are not solid, compact pyrite, but are composed of little balls, strings, and twigs of pyrite, such forms as the concreting mineral is apt to assume, and among these lie the little fossils, all being cemented together by carbonate of lime and silica. On being digested in acid the parts become loosened and the fossils may be taken out.

I think we may interpret these phenomena thus: This little association of species, survivors of some old fauna, was peculiar to limited areas over the bottom of the shallow Genesee sea, where decomposition of organic matter was in progress on a large scale, by means of which the iron sulphate in the sea-water was generally deoxidized. Every change of location of these areas of decomposition carried with it the little fauna until a considerable thickness of the mud of which the Genesee shales are built deposited over and about these spots. But with this hypothesis we would expect that these species would have occasionally strayed into contiguous sediments, or have become entangled by them, though as far as my observation has gone this does not seem to be the case. Further investigation and study, however, is desirable in this direction.

RESUMÉ.

Forty-three species constitute the described fauna and flora of the Genesee rocks of Ontario County Of these forty-three, twenty-eight have been added to the list as the result of these investigations, and there still remain in my possession a number of undetermined Pelecypoda. To this list we must add twelve species identified by other authors from the State of New York (eight of which are "Conodonts," described by Hinde), and the number of known species stands at fifty-five. Eleven of these had pre-existed in the fauna of the Hamilton shales, viz.:

1. *Polygnathus dubius* Hinde.
2. *Polygnathus princeps* Hinde.
3. *Goniatites discoideus* Hall.
4. *Goniatites complanatus* Hall.
5. *Styliola fissurella* Hall.
6. *Tentaculites gracilistriatus* Hall.
7. *Pleurotomaria rugulata* Hall.
8. *Pleurotomaria Itys* var. *tenuispira* Hall.
9. *Chonetes lepida* Hall.
10. *Chonetes setigera* Hall.
11. *Cardiola retrostriata* v. Buch.

The following sixteen pass into the Naples shales:

1. *Polygnathus dubius* Hinde.
2. *Prioniodus spicatus* Hinde.
3. *Paleoniscus Devonicus* n. sp.
4. *Goniatites discoideus* Hall.
5. *Goniatites complanatus* Hall.
6. *Goniatites Patersoni* Hall.
7. *Orthoceras pacator* Hall.
8. *Coleolus aciculum* Hall.
9. *Styliola fissurella* Hall.
10. *Tentaculites gracilistriatus* Hall.
11. *Lunulacardium fragile* Hall.
12. *Cardiola retrostriata* v. Buch.
13. *Melocrinus Clarkei* Williams.
14. *Lepidodendron primævum* Rog.
15. *Lepidodendron Gaspianum* Dn.
16. *Cyclostigma affine* Dawson.

The following eleven, making, with the "Pyrite fauna," twenty-two species, remain peculiar to it, not passing, as far as known, beyond its limits:

1. *Dinicthys Newberryi* n. sp.
2. *Ceratiocaris longicaudus* Hall.
3. *Gomphoceras manes* Hall.
4. *Bellerophon striatus* Ferussac and d'Orbigny.
5. *Leiorhynchus quadricostatus* Van.
6. *Lingula spatulata* Hall.
7. *Lingula concentrica* Vanuxem.
8. *Discina Lodensis* Vanuxem.
9. *Calamites inornatus* Dawson.
10. *Rachiopteris pinnata* Dawson.
11. *Cladoxylon mirabile* Unger.

The Transition Shales.—The shales of the Genesee, properly so called, pass upward into a narrow band of strata similar to them in clastic structure, measuring from 30 to 60 feet in thickness, and this bed I have previously[16] designated as the Transition Shales, intending thereby only to characterize them as strata containing a fauna which shows a well-marked transition from that of the Genesee to that of the Naples shales. These passage beds have more than a merely local development in Ontario County, as they extend westward through the county of Livingston to the Genesee River, especially well developed as a mass of slightly arenaceous, dark shale at Woodville, on Canandaigua Lake and at Bristol Center. I have found the same at Hemlock Lake, and indeed wherever it has been possible to find a profile showing the junction of the Genesee and Naples shales. The fauna is quite sparse and is a commingling of species which in their best development are characteristic of both the overlying and underlying strata. *Lunulicardium fragile* H., a diagnostic fossil of the Genesee, is extremely abundant; *Coleolus aciculum* H., which occurs rarely in the Genesee, but is very abundant and characteristic of the Naples shales; *Cardiola retrostriata* v. Buch, of the Naples shales, *Goniatites complanatus* H., which culminates in the Naples shales; *Styliola fissurella* H., common from the base of the Hamilton to the base of the Chemung, but which culminates in the Genesee; *Pleurotomaria capillaria* H., of the Hamilton and Naples shales, and a *Pleurotomaria* of undescribed species, occurring in the Naples shales are all to be found, and this list, as far as known, constitutes the fauna of these beds. The small fauna is of such a mixed character that it cannot satisfactorily be referred to either the Genesee or the Naples shales, and yet on account of the predominance of *Lunulicardium fragile* and of the petrographical character of the beds it is better left under the Genesee epoch.[17]

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[16] Am. Jour. Sci., Vol. XXV, p. 120, 1883.

[17] It is necessary here to emphasize the fact that these fossils which are to be found in any or all of the horizons of the lower, middle, and upper Middle-Devonian do not lose their diagnostic qualities for the horizons in which they culminate on account of this wide vertical distribution. That is to say, that although *Cardiola retrostriata* occurs in the Marcellus, Hamilton, and Genesee rocks, it is extremely rare at those horizons, and although *Goniatites complanatus* is to be found in the Hamilton shales, it is not a common or characteristic fossil as it is in the Naples shales. *Lunulicardium fragile* has been found in the Naples shales, but it is very rare and is diagnostic of the Genesee, where it culminates.

THE PETROGRAPHIC AND PALEONTOLOGIC CHARACTERS OF THE NAPLES BEDS.

TYPICAL EXPOSURES.

[Those showing the bituminous beds are in italics.]

1. In the town of Naples, the *Parrish*, Caulkins, Clarke, *Snyder*, *Hartranft*, *Grimes*, and Tannery Gullies.
2. In the town of South Bristol, the *Cook*, *Lapham*, *Maxwell*, and *Walton* Gullies.
3. In the town of Bristol, the "*Blacksmith*" and *Randall* Gullies.
4. On Honeoye Lake the *Briggs* and Hamilton Gullies.
5. In the town of Italy, Yates County, the Clark Gully and Whale's Back, on Canandaigua Lake.
6. On *Cashaqua* Creek, Livingston County, near the Shaker Settlement.
7. In the town of *Sparta*, Livingston County, on the Delaware, Lackawanna and Western Railroad.
8. On the Genesee River, below Mount Morris, Livingston County.

In the Report on the Geology of the Fourth District of New York, 1843, Mr. Hall described a series of shales, flags, and sandstones immediately overlying the Genesee shales, under the name of the Portage or Nunda Group, giving it this name on account of "its superior development along the banks of the Genesee River, in the district formerly included in the town of Nunda, now Portage." The term Nunda soon fell into disuse, and the Portage Group, as it has ever since been known, was subdivided into three parts, the first, at the base and immediately overlying the Genesee, the Cashaqua Shale, so called "from its perfect development upon the Cashaqua Creek," in Livingston County, where, according to the description, it consists of a "soft argillaceous rock of a green color, rapidly crumbling on exposure and forming a tenacious clay." At other localities the rock consisted of "a green shale, with thin flagstones and interlaminated sandy shale." The second subdivision was the Gardeau Shales and Flagstones, so called "from their great exposure along the Gardeau Reservation." The rocks here consisted of "alternations of green slaty and sandy shale with black slaty shale, and one or two thin courses of sandstone occurring in the space of 4 or 5 feet. As we ascend the arenaceous matter increases in quantity, the layers are thicker and more numerous, and the shale forms distinct alternations of black and green, often many times in succession, within the space of 50 feet. Toward the upper part the courses of sandstone become too thick for flagstones, and the shale is in thicker masses than below." The third subdivision was the Portage Sandstones, described as thick bedded sandstones, with occasional alternations of shale toward the base.

To the entire Portage group, including these three subdivisions, a thickness was ascribed of not less than 1,000 feet along the Genesee River. More recently Mr. Hall[18] has written that the black slates of the Genesee are "succeeded by a green or olive slate or shale, followed by successive alternations of black and greenish shales, and alternately shales and flagstones, and finally heavy bedded sandstones with intermediate arenaceous shaly partings. The Genesee slate has been regarded as constituting beds of passage to the next formation, known as the Portage group, and this, as well as the succeeding shale, carries a few fossils, which are likewise known in the Hamilton group. The entire formation, consisting of shales and sandstones, and having a thickness of a thousand feet or more in Central New York, diminishes like other strata in a westerly direction. On the shore of Lake Erie it has become a succession of green and black shales and sandstones, with here and there a lenticular mass of heavy-bedded sandstones, with abundant concretions and not infrequently with lenticular masses of calcareous matter."

This entire Portage group is now regarded by Hall and Dana as constituting the earlier epoch of the Chemung period.

In Ontario County the entire series of Portage strata is very perfectly developed, reaching a thickness of between 800 and 1,000 feet, with many fine exposures; and from my study of its development here and in the adjoining counties of Livingston and Yates I present in what follows my evidence for regarding the Portage group, as it is now limited, as a heterogeneous combination of faunas, the earlier of which, that contained by the Cashaqua Shales, and the Gardeau Shales and Flags, belongs with the fauna of the Genesee Shales, and the later, that of the Portage sandstones, to the beginning of the Chemung period.[19]

The order of succession of these strata in Ontario County is as follows:

1. Soft olive green and grayish shales, with occasional thin flagstones. Thickness, from 10 to 15 feet.
2. Black, very bituminous, shales, at the base easily cleavable into large slate-like fragments, higher up much more compact and like the

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[18] Pal. N. Y., Vol. V, Pt. II, p. 151, 1879.

[19] The term Naples Beds or Naples Shales, by which I have here proposed to designate the Cashaqua and Gardeau series, is used advisedly and in accordance with the precedent of adopting local names for formations. My unwillingness to discard historic names led me to attempt uniting the two names Cashaqua and Gardeau into Cashaqua-Gardeau Group (inasmuch as there seems no paleontological evidence here for the separation of the two), but so uncouth and unwieldy a name was suicidal, and I have substituted for it the term Naples Beds, from the town of Naples, Ontario County, where the sections are very perfect, and where the beds have been most carefully studied. The author does not mean to assume, in the absence of complete evidence, applicability for this subdivision outside of the district here discussed.

densest layers of the Genesee. Thickness, about 40 feet. This layer I have termed the Lower Black Band.

3. Alternations of greenish and drab, soft shales, with sandy shales and occasional flagstones, and with abundant spheroidal and fantastically-shaped calcareous concretions, sometimes occurring in layers, often isolated. Thickness, not less than 150 feet.

4. Black shales, in places quite bituminous; the Upper Black Band. Thickness, from 5 to 10 feet.

5. Flagstones, and at the top heavier-bedded sandstones with occasional alternations of sandy shales. Thickness, about 150 feet.

This thickness includes all the rocks, as far as it is possible to judge, which were ascribed by Mr. Hall to the Cashaqua and Gardeau subdivisions, and it is quite possible some of the strata which under his classification belonged to the Portage sandstones. It was naturally difficult to assign definite limits to these subdivisions, as they constantly vary in thickness in passing from east to west, and in a great thickness of conformable shales and sandstones it is often quite impossible to draw fixed planes of division.

This series of strata carries us to the lowest horizon of the Chemung rocks, that is, to the horizon of the first fossils which belong to the Chemung fauna. The separation of Cashaqua and Gardeau strata is not a good one petrographically, as the entire series of strata from the top of the *transition shales* to the base of the Portage Sandstones shows only a gradual, though regular, transition from the shaly sediments below to the sandstones above.

In the order of succession given, the shales included in subdivision 1 contain *Cardiola retrostriata* in great abundance, *Goniatites complanatus*, *Lunulicardium acutirostrum*, *L. ornatum*, *Cardiomorpha suborbicularis*. In subdivision 3 the softer shales contain the same species, and a large number of others. Indeed, it is here that the fossils of the group, never very abundant, have been mostly found. One may search, as Mr. Hall has said, an entire day in these rocks and find nothing or but very little, and though some species are very widely distributed and in places quite abundant, *e. g.*, those just mentioned, the entire group is to be regarded as comparatively barren of organic remains. At the beginning of these investigations only twenty-one species had been described from the Portage group, a number which is now increased to seventy-four.

The Bituminous Shales.—These beds, which occur in two fairly-well defined horizons in Ontario County, as the Lower and Upper Black Bands, retain their persistence into the county of Livingston, the Upper Band being finely developed in the township of Sparta, along a cutting on the Delaware, Lackawanna and Western Railroad, and also 1½ miles south of the Shaker Settlement on Cashaqua Creek. Further west they lose their persistency and become a series of thin beds alternating with the greenish shales and flagstones. The Lower Band has afforded but very few fossils, some undetermined ganoid scales from Snyder Gully, in Naples, with *Goniatites Chemungensis* H. *var.* In the same strata, at Bristol, I have found *Spathiocaris Emersoni* Clarke, and some undetermined placoderm plates. The Upper Band is somewhat richer in organic remains, and has afforded from Naples, *S. Emersoni* Clarke, *Polygnathus dubius* Hinde, *Prioniodus spicatus* Hinde, *P. erraticus* Hinde. These species of Conodonts are comparatively abundant in Naples, at the foot of Hatch Hill, where they are associated with large quantities of vegetable remains, apparently the stipes of ferns, and accompanied with very much pyrite. They also occur at Sparta, in the same horizon. At Sparta occur also the following:

Paleoniscus Devonicus, n. sp.
Acanthodes pristis, n. sp.
Lepidodendron primævum Rogers.
L. Gaspianum Dawson.
Cyclostigma affine Dawson.
Sporangites Huronensis Dawson.
Various undetermined fish remains.

The Goniatite Concretionary Layer.

This is an unusually interesting stratum, which lies at an elevation of about 150 feet above the top of the *transition shales*. It is largely calcareous, with a considerable intermixture of silica and alumina, and a freshly-broken surface shows compact, evenly-grained structure, like phthanite, gives a dark or sometimes bright red color mixed with considerable green, and passing usually at the surface into a light gray. In Parrish Gully, Naples, 60 feet above the first outcrop at its entrance, where is to be found the best exposure of the rock, the stratum which has been denuded of its overlying shales by the water of the gully-stream shows the peculiar surface of a concretionary layer, looking as though it had been kneaded, and where the shales overlie or underlie in the adjoining banks it is noticeable that they conform to this irregular surface. This concretionary tendency was so general at the time of the formation of the layer that the stratum itself is to be regarded as a concretionary mass, rather than a mass of concretions. From Parrish Gully it can be traced southward to Caulkins Gully, and on the opposite (west) side of the Naples Valley Mr. Luther has observed it in the Clarke Gully. In all of these outcrops the rock retains its characteristic color, contains considerable pyrite, but in its distribution loses somewhat of its silicious character and becomes more readily separable into the individual concretionary masses of which it is composed. The rock is extremely tough and hard to work, and plays havoc with hammers and chisels. The layer has a thickness of 8 inches or a foot, and is immediately overlain by a bed of soft shales with a thickness of 4 feet, filled with separated concretions molded into a great variety of fantastic shapes, and which when broken show often the red and green tints of the layer below. These peculiarities of color and structure in these layers have not, as far as I know, been noticed elsewhere in the American Devonian, but they are very forcibly suggestive of the reddish, greenish, and grayish concretionary Kramenzelkalk of the Rhine Provinces and Westphalia. This similarity is so marked that a person familiar with both the New York and the German rocks might easily confound hand specimens without fossils, from the different countries. Especial emphasis is to be laid upon this resemblance on account of the nature of the fauna which this Naples formation contains. It is indeed insignificant in its development compared with that of the Kramenzelkalk or of the Goniatitenschichten, but nowhere above the Marcellus shales of the lower Middle-Devonian are Goniatites so abundant as here. This is an abundance in individuals and not in species, but nowhere in the Upper Devonian of America are Goniatites to be regarded as abundant fossils. Here occur the species *Goniatites Patersoni* H. (cf. *G. intumescens* Beyr.), *G. discoideus* H. (cf. *G. simplex* v. Buch), and *G. sinuosus* H., in comparatively great abundance and generally having served as nuclei for the concretionary masses. These features have a marked bearing upon the parallelism of the American and German Upper Devonian, and it seems evident that the same environment which produced in Germany the Flinz and Knotenkalk of the lower Upper-Devonion and the Kramenzelkalk of the higher Upper-Devonian produced this concretionary layer also in the upper portion of the lower Upper-Devonian in New York. Recently F. Roemer has noted (*Zeitsch. d. deutsch. geolog. Gesell., Vol.* XXXI, *p.* 659) the occurrence in Lower Dunscombe, Devonshire, of a slight development of a Nierenkalk with *Goniatites intumescens* and other fossils occurring in the fauna of the Goniatitenschichten, a fact which bears out the supposition that we may have here in New York the remotest westward extension of the Goniatitenschichten.

This layer contains the following fauna:

1. *Goniatites discoideus* Hall.
2. *G. Patersoni* Hall.
3. *G. sinuosus* Hall.
4. *Orthoceras pacator* Hall.
5. *Coleolus aciculum* Hall.
6. *Styliola fissurella* Hall.
7. *Tentaculites gracilistriatus* Hall.
8. *Euomphalus planodiscus* Hall.
9. *Loxonema Noe* n. sp.
10. *Platyostoma minutissima* n. sp.
11. *Cardiola retrostriata* v. Buch.

REVIEW OF THE FAUNA AND FLORA OF THE NAPLES BEDS.

PISCES.

"CONODONTS."

In the present state of our knowledge of these bodies it is not possible to assign them an exact position in a zoological classification. The original species early described by Pander from the Lower Silurian of Russia were regarded as the teeth of minute fishes, a conclusion which has been supported by Newberry, Hinde, and Nicholson. Similar bodies from the Lower Silurian have been regarded by Harley (Quar. Jour. Geol. Soc., Vol. XVII) as the spinous attachments of crustacean segments. Hinde, James, and, earlier, Grinnell have described allied forms from the Silurian and Middle Devonian as teeth of annelids. The microscopical study of the structure of these bodies by Hinde (Quar. Jour. Geol. Soc., Vol. XXXV) makes it probable that, as far as the species here mentioned are concerned, they are correctly referred to the Myxinoid fishes.

Genus POLYGNATHUS.

1. Polygnathus dubius.

Polygnathus dubius Hinde, Quar. Jour. Geol. Soc., 1879, Vol. XXXV, p. 362, Pl. XVI, Figs. 6–18.

Individuals of this species occur quite abundantly in the Upper Black Band where it outcrops on Hatch Hill, in Naples, overhanging the banks of the Naples inlet, and occasionally in the same horizon in the town of Sparta, Livingston County. They are associated with large quantities of vegetable remains, presumably the stipes of ferns, and much pyrite. My material shows forms agreeing with some of the remarkable variations of the species as figured by Hinde, but are confined to those he has designated as pectinated and fimbriated teeth. The crested variation has not as yet been observed. The individuals measure from 1 to 2^{mm} in length.

Genus PRIONIODUS.

2. Prioniodus erraticus.

Prioniodus erraticus Hinde, Quar. Jour. Geol. Soc., p. 359, Pl. XV, Fig. 14.

This species is marked by the comparatively greater distance between the cusps than in the former, and several individuals in my possession from Hatch Hill agree well with the description.

3. Prioniodus spicatus.

Prioniodus spicatus. Hinde, Quar. Jour. Geol. Soc., p. 361, Pl. XVI, Figs. 1–3.

A single individual shows the strong terminal cusp extending below the base of the tooth, which characterizes the species.

These "Conodonts," although known from various horizons from the Lower Silurian to the Carboniferous, have not been before noticed from this.

Genus PALÆONISCUS.

4. Palæoniscus Devonicus, n. sp.

(Plate I, Figs. 2–6.)

Numerous specimens of individuals referable to this genus have been obtained from the railroad cutting through the bituminous layers in the town of Sparta. These are usually fragmentary, but one individual retains most of the body in place though the bones of the head have been displaced and scattered and the tail is somewhat crushed. The animal was originally about 13^{cm} in length. The cranial bones, which are found abundantly scattered through these layers, though not as yet found in juxtaposition, with the exception of those represented in Fig. 6, are characteristically marked by punctate incised lines which run along the greatest diameter of the bone, occasionally, as in Fig. 5, radiating from the most convex portion of the plate. It is quite probable that the plates in Fig. 6 represent the *parietals*, Figs. 4 and 5 the *frontals* or *squamosals*. Associated with these bones are many minute, shining, somewhat flattened, conical teeth, measuring $\frac{3}{4}$–1^{mm} in length. The scales, except those on the dorsal ridge, are 1$\frac{1}{2}^{mm}$ long and $\frac{5}{8}^{mm}$ wide, subrhomboidal in outline and very beautifully sculptured with strong elevated striæ, which take their origin at the upper forward angle and pass obliquely across the scale, the forward edge presenting the appearance of being strongly tucked. These elevated striæ become very much stronger at the posterior edge, and in this region, the upper portion of the scale being left free of striæ, shows strong punctate markings. These pittings are also to be seen in the furrows between the striæ on the anterior portions of the scale.

The median dorsal scales are large, spatulate in form, measuring 3$\frac{1}{2}^{mm}$ in width anteriorly, and narrowing backwards to 1$\frac{1}{2}^{mm}$; length 4^{mm}. Surface strongly punctate. Dorsal fin, somewhat posterior. Ventral and anal fins not well preserved.

A single scale of this species I have also from the Genesee shales at Glenville, Honeoye Lake, which brings the first appearance of this species to a still lower horizon.

Scales of *Palæoniscus* have been mentioned by Hinde[20] from the Genesee shales of North Evans, Erie County, and Dana[21] has noticed the occurrence of *Palæoniscus* in the Black shales of Kentucky, a horizon which corresponds to the Genesee shales of New York, but I have no knowledge of the description of the species.

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[20] Quar. Jour. Geol. Soc., Vol. XXXV. [21] Manual of Geology, 3d ed., 1880, p. 275.

P. Devonicus is, I believe, the first species of this genus described from Devonian rocks.

Genus ACANTHODES.

5. Acanthodes (?) pristis n. sp.

I refer to this genus a specimen from the same locality as the preceeding, the description of which is justified, although the specimen is fragmentary, because of the extreme scarcity of icthyic remains in these rocks which are well enough preserved to allow of identification. The specimen consists of a large portion of the body of the fish, the head and tail being lost. The scales are very small, measuring 0.5^{mm} on the edge, square or slightly subrhomboidal in outline and one-fourth as thick as wide. The adjacent edges at about two-thirds the distance from the upper surface are strongly grooved by a single deep furrow. The upper surface of the scales is smooth and slightly convex. In the character of its scales the species stands in harmony with the genus *Acanthodes*, though it is impossible to determine its generic relations definitively without knowing more of its fins and head.

Genus PRISTACANTHUS.

Pristacanthus Agassiz, Poissons Fossiles, Tom. III, p. 35, Tab. VIII*a*, Figs. 11, 12, 13.

This genus was founded by Agassiz to include a peculiar spine from the Stonesfield Oolite and the Calcaire de Caen, which was described under the name *P. securis*. From the original diagnosis the following are found to be distinctive features:

1. The very thin and fragile substance of the spine.
2. Absence of any ornamentation of the surface beyond a very fine granulation.
3. The serrate character of the tooth-like lateral processes, which occur only on one side of the spine.

From the upper portion of the Naples shales, near Milo, Yates County, I have a single spine which agrees with this genus in the first two particulars, but the lateral tooth-like processes are not so evenly serrate as in the original species.

It agrees, however, as far as I am aware, with no described genus so well as with *Pristacanthus*, and, in the opinion of Dr. Newberry, to whom the specimen was submitted for examination, may be safely placed under this genus.

6. Pristacanthus vetustus, n. sp.

(Plate I, Fig. 7.)

A fragment of a spine measuring 70^{mm} in length, 8^{mm} in width at the distal extremity. The posterior edge is somewhat broken away, but it appears from the portion that remains uninjured that the spine tapered very gradually from base to apex.

The anterior edge bears fourteen serrations, which are stronger at the proximal edge. These have a strong backward bend, the upper edge curving evenly outward and downward and meeting the lower edge at an angle of about 60°. The lower edge meets the margin of the spine at nearly a right angle. Substance of the spine exceedingly thin, measuring scarcely 0.02^{mm}, except at the extremities of the serrations, where it thickens to 0.5^{mm}. The surface of the spine is smooth and almost flat, showing under a glass fine granulations or minute pustulations. This is the only example of the species I have seen, and represents the first occurrence of this genus in Paleozoic rocks.

A large number of undetermined scales and plates of fishes from the bituminous layers at the Sparta railroad cutting are in my possession.

ANNELIDA.

Genus SCOLITHUS.

7. Scolithus verticalis.

Scolithus verticalis Hall; *Fucoides verticalis* Hall, 1843, Geol. N. Y., Survey Fourth Geol. Dist., p. 242.
Scolithus verticalis Hall, 1852, Pal. N. Y., Vol. II., p. 242.

In the upper sands of the Naples shales and also in the higher sandstones of the Portage beds this fossil is quite abundant. I regard it as the tubular boring of some annelid rather than the remnant of vegetable life, as the tubes usually show evidence of having been filled from the top by sediments which, in being carried into the *cavities*, has arranged itself in successive concave layers. Such-worm borings occur in various horizons in Paleozoic rocks. Mr. Hall applied the name *Scolithus verticalis* to similar tubular borings from the Medina sandstone, and as there exists no appreciable difference in the appearance of these simple tubes I use the name for the Naples shales specimens instead of retaining the doubtfully valuable generic term *Fucoides*.

CRUSTACEA.

Genus CERATIOCARIS.

8. Ceratiocaris simplex, n. sp.

(Plate II, Fig. 2.)

The fossiliferous shales immediately underlying the concretionary limestone of Parrish Gully have afforded three specimens of this species, the most clearly defined of which is shown in the figure. The carapace is somewhat oval in outline. At its anterior extremity it shows a retral angular notch, above which is a slight prolongation in the median axis. The dorsal and ventral edges show a well-defined margin, which is somewhat thickened, giving a noticeable rim to the carapace. Carapace convex, rising more abruptly from the dorsal margin and deflected gently to the ventral edge. No ocular node visible. Length of the carapace, figured, 30^{mm}; greatest width, somewhat anteriorly, 10^{mm}.

9. **Ceratiocaris Beecheri**, n. sp.

(Plate II, Fig. 1.)

From the shales of Cashaqua Creek, Livingston County, I have one individual showing three abdominal segments and the caudal spines. These are apparently too large to refer to the foregoing species, and as I have not as yet observed the body-segments in the layers in which *C. simplex* occurs, it is necessary to regard this form a distinct species.

Of the segments here preserved the first has been somewhat detached from its neighbor and its anterior a little broken away. What remains measures 6^{mm} in width and 3–4^{mm} in length. The next segment is normal in its proportions, is 8^{mm} in length and 5 in width. The caudal plate is 4^{mm} in length and subtriangular, from the extremity of which is prolonged the strong central caudal spine. In the specimen this spine has been flattened horizontally and been given thus an apparently greater width than the lateral spines, which have been laterally compressed. The width of this spine across the proximal end is 3^{mm}, that of the left lateral spine 2^{mm}, and its length 12^{mm}. A strong medial ridge passes along the middle spine, taking its origin 1^{mm} from the edge of the caudal plate, where it is quite strong, and continuing through the entire length of the spine as far as visible. The left lateral spine also shows evidence in the external margin of such a medial ridge. The substance of the spines is very delicate, but shows the characteristic pseudo-vascular markings of these crustacea. Of the right lateral spine but a small portion remains, and the insertion of these lateral spines upon the caudal plate is not visible. The first two segments show, on account of the flattening to which they have been subjected, no trace of ornamentation except at the angles of the segments a low inconspicuous tubercle, two on the first segment and four on the second.

I take pleasure in giving to this species the name of Mr. C. E. Beecher, of the New York Geological Survey.

Genus ECHINOCARIS.

Echinocaris Whitfield, Am. Jour. Science, 3d ser., Vol. XIX, No. 109, p. 34.

This genus was erected in 1880, in the place cited, in a paper On New Forms of Fossil Crustacea from the Upper Devonian Rocks of Ohio, and was made to include a series of forms belonging to the Ceratiocaridæ, one of which at least (*E. armatus* H.) had been previously described as *Ceratiocaris*. These differ from *Ceratiocaris* in the peculiar pustulose, nodose, and ridged character of the ornamentation of the carapace, the number of abdominal segments (4 known in *Echinocaris*, 5 or 6 in *Ceratiocaris*), and the spinose attachments to the latter. The author of the genus has described three species from the Erie shales of Ohio, a horizon which probably parallelizes with the Naples shales.

10. Echinocaris Whitfieldi, n. sp.

(Plate II, Figs. 3 and 4.)

Carapace with a straight hinge-line extending two-thirds its length, at the posterior extremity of which the margin is abruptly deflected at almost right angles. Ventral margin with a suboval curve rounding abruptly posteriorly and less so anteriorly. Rostral region somewhat produced, posterior extremity truncated. The margin on all sides marked by an elevated rim, most prominent on the ventral and dorsal portion. The surface is marked by fine tubercles, which are principally grouped about the cephalic portion. Six or seven quite strong elongate pustules mark the position of the anterior tubercle, below and behind which lie a number smaller and indefinitely scattered, with the exception of three or four, which make a vertical row behind the anterior tubercle, as shown in Fig. 3. Near the posterior dorsal angle, on the dorsal margin and at the posterior ventral angle, are three isolated single pustules. A well-marked but short ridge is found on the anterior portion running parallel with the anterior margin, and further backwards on the carapace are a few low ridges lying in the circumference of a circle, about and within which the finer sculpture is concentric. Under a glass the surface shows very fine and delicate scaly markings. The same fragment of shale which contains the carapace affords also the specimen of the caudal plate and spines shown in Fig. 4.

The telson consists of a subtriangular caudal plate, which is prolonged into a middle spine. To the underside of the plate the two lateral spines are jointed, although the left lateral spine is lost. Of the spines the middle one is the shortest and stoutest; all are marked with a slight ridge along the center, and both they and the caudal plate are covered with comparatively strong tubercles.

The carapace measures 27^{mm} in length and 16^{mm} in width.

From the shales of Hatch Hill, Naples.

Genus SPATHIOCARIS.

Spathiocaris Clarke, 1882, Am. Jour. Sci., 3d ser., Vol. XXIII, p. 477, Plate.

This genus was founded to include some crustacean shields, allied to *Discinocaris* Woodward, characterized by their oval-elliptical outline, triangular anterior rostral opening, and lack of a dorsal suture. It is very closely similar to Woodward's genus *Cardiocaris*; indeed from it only in having the posterior margin rounded instead of very faintly notched. In a later publication[22] on these crustacea I gave my reasons for regarding the genus *Cardiocaris*, which was proposed subsequently to *Spathiocaris*, as in part at least identical with it. The committee, consisting of Mr. R. Etheridge, Dr. H. Woodward, and Professor T. Rupert Jones, appointed by the British Association for the Advancement of Science to report upon the classification of the Fossil Phyllopoda of the Paleozoic Rocks, have not admitted[23] the identity of the two genera, but have taken from each and placed elsewhere some of the original members of each genus, so that *Spathiocaris* is regarded by them as represented by two species, *S. Emersoni Clarke* and *S. ungulina Clarke.*

The differences in the genera *Discinocaris*, *Cardiocaris*, and *Spathiocaris* are so slight that I willingly concede the rearrangement by the committee of the species described by me from the Upper Devonian of Bicken, viz., *S.* (Discinocaris) *congener*, *S. ungulina*, *S.* (Cardiocaris) *Koeneni*, *Cardiocaris* (Discinocaris) *læta* H. Woodward. Objections have been made to the classification of any of these forms of the Discinocarida with the Crustacea. Among the earlier observers Keyserling and F. A. Roemer, and at the present Dames, Kayser, and perhaps others, have regarded them as a whole or in part as having had some organic connection with the Cephalopoda, with which they are sometimes associated. My description of the species occurring at Bicken called forth a vigorous reply from Professor Dames,[24] whose arguments have been sufficiently answered by subsequent writers upon the subject.[25]

11. Spathiocaris Emersoni.

Spathiocaris Emersoni Clarke, Am. Jour. Sci., 3d ser., Vol. XXIII, p. 476, Plate, Figs. 1–3.

This species is the only well defined fossil known to me from this district which passes from the fauna of the Naples shales into that of the Chemung group. I have already quoted the species from the following different horizons (Am. Jour. Sci., 3d ser., Vol. XXV, p. 120):

1. In the lower black band of Bristol.
2. About 150 feet above the transition shales of the Genesee in the town of Naples.

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[22] Ueber deutsche oberdevonische Crustaceen, Neues Jahrbuch, 1884, Vol. I, p. 178.

[23] 2d Report at the Montreal meeting, September, 1884.

[24] See also Dames in Neues Jahrbuch, 1885, Vol. I, pp. 275, 279.

[25] See von Koenen, Neues Jahrbuch, 1884, Vol. I, pp. 45, 46.

Report of the committee, consisting of Mr. R. Etheridge, Dr. H. Woodward, and Prof. T. Rupert Jones (secretary), on the Fossil Phyllopoda of the Paleozoic Rocks. 1883, pp. 2, 3.

Jones and Woodward, Geological Mag., Dec. III, Vol. I, No, 8, pp. 348–355. 1884.

Second Report of the Committee on Fossil Phyllopoda. 1884.

A. S Packard, jr., A Monograph of North American Phyllopod Crustacea. 1883, p. 451.

3. At approximately the same horizon in the town of Richmond.
4. In the upper black band, 540 feet above the transition shales, Naples.
5. At approximately the same horizon 1½ miles south of the Shaker Settlement, along Cashaqua Creek, Livingston County.
6. At approximately the same horizon in the Delaware, Lackawanna and Western Railroad cutting in Sparta.
7. In the shales immediately overlying (4).
8. In the Portage sandstones at Portageville, Wyoming County.
9. In the lowest stratum of the Chemung, Naples.
10. In the sandstones of the Lower Chemung, in the town of Canadice, Ontario County.

CRUSTACEAN TRACKS. (?)

Twenty-five feet above the first outcrop of the Naples shales in Parrish Gully occurs a bed of sandy gray-greenish shales which are filled with peculiar impressions unassociated with any traces of organic matter. These are usually 2 or 3 inches in length, and consist of two rows lying side by side, of little concavities, each concavity measuring 2^{mm} in diameter. They suggest the Neritoides, described by Richter,[26] from the sandy shales of the Lower Devonian of the Thuringian Forest, although they are always much shorter than the European specimens. These seem to me to be the result of the wallowing of some crustacean, such as we may assume would be made by the known crustaceans of these rocks, not as they crept along over the soft mud of the sea-bottom, but in coming to a position of rest from swimming. A slight, constant vibratory motion of the appendages would produce such impressions in the mud. These markings I have found higher in these shales, as in the Tannery Gully in Naples, but they prove to be most abundant in the lower outcrops.

CEPHALOPODA.

Genus GONIATITES.

Type of **Goniatites simplex** von Buch.

12. Goniatites complanatus.

Goniatites complanatus Hall, 1843, Geol. N. Y., Survey Fourth Geol. Dist., 1879. Pal. N. Y., Vol. V, Pt. II, p. 455.

This species, which is very abundant and characteristic of these shales, occurs with considerable variation of size. From the thin flagstones of the upper portion of the beds I have some large individuals measuring 10^{cm} in diameter, but the usual forms in the shales are much smaller, averaging about 25^{mm}, the smallest noticed having a diameter of 4mm. Specimens well enough preserved to show any trace of the septa are difficult to find, and I have not as yet seen any such from the soft, muddy shales. A few specimens from the sandy layers retain these septal sutures, though without showing distinctly the character of the dorsal lobe. Hall has figured one[27] example showing in part, the character of the septa, and my own specimens give this feature more perfectly. There is a marked similarity in the character of these sutures and those of *G. lamed* Sandberger,[28] of the Cypridinen-Schiefer and Goniatiten-Schichten. In the variety ***rugosus*** (Fig. 4) which is probably the young of some species like ***G. intumenscens***, the curves of the suture are quite the same. In the var. ***complanatus*** (Fig. 5) the lateral saddle is somewhat stronger, and the distance between successive sutures greater than in *G. complanatus* H. In this variety, however, there is a noteworthy agreement in the form of the shell itself.

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[26] Beitrag z. Paläon. d. Thuring. Wald., p. 48, Taf. III, Figs. 42–44.

13. Goniatites discoideus.

Goniatites discoideus Hall, 1860, Thirteenth Ann. Rep. N. Y. State Cab. Nat. Hist., p. 97, Figs. 3–6, 1879; Pal. N. Y., Vol. V, Pt. II, p. 441.

This species, which has hitherto been regarded as characteristic of the Marcellus shales, I have found in the concretionary limestone of Parrish Gully, Naples, and in the calcareous concretions on Honeoye Lake. It is a form in every respect comparable to ***G. retrorsus*** (= ***G. simplex*** v. Buch), as figured by Sandberger,[29] and Keyserling,[30] in the character of the sutures, the non-umbilicated shell, and the nature of the surface markings.

14. Goniatites uniangularis.

Goniatites uniangularis Conrad, 1842, Jour. Acad. Natural Science, Vol. VIII, p. 268, Pl. XVI, Fig. 4. 1879, Pal. N. Y., Vol. V, Pt. II, p. 444, Pl. LXXI, Fig. 14.

A species which presents a little variation from the foregoing in its sutures, and which is quoted by Hall from the Portage; I have, however, seen no examples of it from Ontario County.

Type of Goniatites intumescens Beyrich.

15. Goniatites Patersoni.

Goniatites Patersoni Hall, 1860, Thirteenth Ann. Rep. N. Y. State Cab. Nat. Hist., p. 99, Figs. 9–10; 1879, Pal. N. Y., Vol. V, Pt. II, p. 464.

A somewhat abundant species in the concretionary layer of Parrish Gully and in the immediately overlying and underlying shales. I very much doubt the advisability of retaining this specific name, as I am unable to distinguish any differences between this species and *Goniatites intumescens* Beyr., the most abundant Goniatite in the Upper Devonian of Germany. A study of a large number of these American and European forms leads me to believe that whatever variation there may be in *G. Patersoni* from the typical forms of *G. intumescens* as figured by the brothers Sandberger,[31] which indeed is very slight, there is a far wider variation among the forms which are in Europe referred to this species.

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[27] Pal., N. Y., Vol. V, Pt. II, Pl. X, Fig. 8.

[28] Verstein. d. Rhein. Schichten Syst. in Nassau, 1850–'56, p. 90, Pl. VIII, Figs. 4–9.

[29] *Loc. cit.* Pl. X, Fig. 15.

[30] Eine Reise in das Petschoraland, 1846, Pl. XII, Fig. 5.

(Cf. *loc. cit.*, Pl. VII, Fig. 3. Roemer's Lethæa Palæozoica, 1876, Pl. XXXV, Fig. 10.)

This similarity lies not alone in the character of the suture as shown above, but also in the amount of umbilication and in the caliber of the shell. The form from the Naples shales is never so carinate as in some of the European varieties, but agrees perfectly with the typical forms of the species.

16. Goniatites bicostatus.

Goniatites bicostatus Hall, 1843, Geol. N. Y., Survey Fourth Geol. Dist., p. 246; 1879, Pal. N. Y., Vol. V, Pt. II, p. 450.

This species was referred by Ferd. Roemer and De Verneuil (*vide* Sandberger, *op. cit.*, p. 101) to *G. retrorsus* v. Buch. Mr. Hall (Pal. N. Y., Vol. V, Pt. II, p. 453) has noticed the similarity between *G. bicostatus* and some of Sandberger's varieties, as follows: "In the manner of its septa it is very closely similar to the variety *lingua*" (*G. simplex* v. Buch, Kayser[32]) "and variety *typus*" (the same) "of that species, while the variety *undulatus*" (*G. undulatus* Sandb., Kays.) "represents the surface markings and the revolving carinæ." This is a rare species in the Naples shales.

17. Goniatites sinuosus.

Goniatites sinuosus Hall, 1843, Geol. N. Y., Survey Fourth Geol. Dist., p. 244; Pal. N. Y., Vol. V., Pt. II, p. 460, Pl. LXX, Figs. 13–15, Pl. LXXII, Fig. 11; Pl. LXXIV, Fig. 11.

Goniatites (*Clymenia?*) *Nundaia* Hall, 1875, Twenty-seventh Ann. Rep. N. Y. State Mus. Nat. Hist.

In the closer parallelism of its sutures and the sinuous sculpture of the surface this species differs from *G. Patersoni*. In its other features it is quite closely allied to it, and is not infrequently associated with it. Occurs not uncommonly in the concretionary layer of Parrish Gully.

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[31] *Loc. cit.*, Pl. VII, Figs. 1 and 2.

[32] Zeitsch. d. deutsch geol. Gesell., Vol. XXV, p. 620, 1872.

18. Goniatites Lutheri, n. sp.

(Plate II, Fig. 8.)

Shell widely umbilicated, more so than any species with which it is associated, not excepting *G. complanatus*. Septa numerous and closely appressed, the individual figured having thirty-eight in the last whorl. The sutures are characterized by their very acute lobes and saddles. Ventral saddle very small, short and very slightly rounded, the two lateral lobes strong and acute. The lateral saddle very strong and acute, with its sides somewhat rounding. The dorsal saddle well defined and rounded, with a slight sharp carinal lobe. In the figured example the carinal portion of the shell has been somewhat folded upward, giving an abnormally thick margin to the shell. The septa are so closely crowded together that they are very nearly parallel to each other except at the apices of the lateral saddles, where the distance between them is somewhat greater than elsewhere. Surface markings are shown in some of the examples preserved in pyrite as finely incised, equidistant lines, curving gently forward over the lateral portions of the shell and more strongly forward as they near the dorsal surface. This is a very graceful species and quite distinct from any known forms belonging to the type of *G. intumescens*. Most closely allied to it is *G. forcipifer* Sandberger,[33] the closely oppressed septa of which suggest *G. Lutheri*, but there is a difference that is very marked in the acute lateral saddle and ventral lobe. This species I have seen in a few examples from the shales which overlie the concretionary limestone of Parrish Gully, and from Honeoye Lake.

19. Goniatites peracutus.

Goniatites peracutus Hall, 1879, Pal. N. Y., Vol. V, Pt. II, p. 463, Pl. LXIX, Fig. 8.

Suture characterized by the presence of but two instead of three saddles, as with other species of the group of *intumescens*-like forms. The dorsal saddle is also very acute. The species has been described from a fragment of the outer volution, and is "from the Portage or Lower Chemung, at Ithaca, N. Y." I do not know the species from Ontario County.

20. Goniatites complanatus, var. perlatus.

Goniatites complanatus, var. *perlatus*, 1874, Descriptions of New Species of Goniatitidæ, p. 1, Hall, 1879, Pal. N. Y., Vol. V, Pt. II, p. 458, Pl. LXX, Fig. 12.

This form varies from the original species in the greater distance of the septa from each other. Hall's example is "from the lower beds of the Portage group at Homer, Courtland County, New York." I am not sure that I have seen specimens referable to this variety.

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[33] *Op. cit.*, p 82, Pl. VI, Fig. 3.

Type of Goniatites clavilobus Sandberger.

21. Goniatites Chemungensis. Variety.

Goniatites Chemungensis Hall, 1879, Pal. N. Y., Vol. V, Pt. II.

I have a single specimen from the very bituminous layers of the lower black band, in Snyder's Gully, Naples, which is the only determinable fossil, with the exception of *Spathiocaris Emersoni*, that has been found in these rocks. In its tuberculated whorls the specimen agrees with *G. Chemungensis*, but differs from Mr. Hall's description of that species in the greater number of these marginal tuberculations on each edge of the whorls. It does not agree well with the var. *æquicostatus* Hall, and I do not attempt any further identification of it.

Genus ORTHOCERAS.

22. Orthoceras pacator.

Orthoceras pacator Hall, 1879, Pal. N. Y., Vol. V, Pt. II, p. 307, Pl. LXXXIX, Fig. 16.

The flattened condition in which this species is usually found in the fossiliferous shales has not allowed any evidence as yet of the position of its sipho. It is by no means an uncommon fossil.

23. Orthoceras aciculoides, n. sp.

(Plate II, Fig. 11.)

Shell small, sides almost parallel. The specimen from which the figure has been made is 10^{mm} long and 1^{mm} wide. It shows six septa which are remarkable for their unusual distance from one another. The first of the air-chambers measures 2^{mm} in length, the second $2\frac{1}{3}^{\mathrm{mm}}$, the third $2\frac{1}{2}^{\mathrm{mm}}$, the fourth 3^{mm}, the fifth $3\frac{1}{2}^{\mathrm{mm}}$, the sixth is partially broken away. Siphuncle and surface sculpture unknown. This little species is quite distinct from any member of this genus in the Devonian fauna. Many of the individuals which had usually been referred to the species *Orthoceras aciculum* Hall, 1843, and which show very plainly such distant septa and subparallel sides, may be, since the erection of that species by its author into *Coleolus aciculum*, referred to *O. aciculoides*. The specimen figured is from the lower shales of Cashaqua Creek.

24. Orthoceras Ontario, n. sp.

(Plate III, Fig. 1.)

This is a representative of the annulated Orthocerata, in which the annulations are relatively distant and consist of very narrow, low, and acutely angled elevations. The distance between them increases with slight irregularities from apex to stoma, and the shell, which measures 14^{cm} in length, bears thirty of them. These rings slope abruptly to the surface of the shell, making the interspaces generally quite flat.

In these interspaces where the surface has been best preserved there is a fine sculpture of the test visible, consisting of minute, microscopic, longitudinal striations. Septa evenly transverse and regularly concentric. Sipho simple, central. The original of the species was taken from the concretionary shales in Parrish Gully, Naples, is preserved in crystalline calcite, and its form is thus retained without the distortion which usually occurs in the Orthocerata from these shales. As yet I know of but this specimen. The longitudinal ridge represented in the figure is a line of the attached matrix, which has been made too prominent by the artist.

25. Orthoceras filosum, n. sp.

(Plate II, Figs. 12, 13, 14.)

Conf. Orthoceras anguis Hall, Pal. N. Y., Vol. V, Pt. II, p. 312, Pl. LXXXIX, Fig. 9.

Shell tapering rapidly from stoma to apex. Test very thin and covered with finely incised lines from $\frac{3}{4}$ to $1\frac{1}{2}^{mm}$ apart. The nature of this sculpture is such that the surface of the shell is given an imbricate appearance. These lines pass about the shell in long, low undulations, which are not parallel to the outline of the stoma. The septa and sipho have not yet been noticed. This Orthoceras is interesting as the only representatives in the Devonian to my knowledge of a group after the type of *O. socium* Barrande, the forms quite characteristic of the Etage E.

The peculiarity of the entire group is the thin test, undulating and imbricating concentric lines of surface sculpture, with no longitudinal markings. I have before me several examples of this species, one from Parrish Gully, Naples, one from Hatch Hill, one from Briggs' Gully, Honeoye Lake.

GASTROPODA.

Genus BELLEROPHON.

26. Bellerophon natator.

Bellerophon expansus? Sowerby, Hall, 1843, Geol. N. Y., Survey Fourth Geol. Dist., p. 244.

Phragmostoma natator Hall, 1862, Dec. new species of Fossils (Fifteenth Ann. Rep. N. Y. State Cab. Nat. Hist.); 1876, Illustrations Dev. Fossils; not *Phragmostoma natator* Hall, 1862, Fifteenth Ann. Rep. N. Y. State Cab. Nat. Hist., explanation of plate.

Bellerophon natator Hall, 1879, Pal. N. Y., Vol. V, Pt. II, p. 108.

Much confusion exists in regard to both the synonymy and the identity of this species. The original example consisted of a portion of the outer volution of the shell from the Portage (Naples) group, which was identified by Hall in 1843 as *Bellerophon expansus?* Sowerby. Subsequently, in the Fifteenth Annual Report to the Regents on the Condition of the

State Cabinets, the species was regarded as the representative of another genus on account of the supposed evidence of a transverse septum within the body whorl, and was referred to the genus *Phragmostoma* (Hall, 1861, Fourteenth Ann. Rep. N. Y. State Cab. Nat. Hist.) as *P. natator*. To this description illustrations were accidentally appended of *P. cymbula* H., of the Hudson River group (*vide* Pal. N. Y., Vol. V. Pt. II, p. 108). In the final review and description of the species, it is removed from the genus *Phragmostoma* on account of unsatisfactory evidence of the existence of the transverse septum and relegated to the genus *Bellerophon*. In this connection Hall states that the original specimen from the Portage, upon which the species was founded, was not accessible to him, and the species as illustrated by him in the Illus. of Dev. Fossils, 1876, and in Pal. N. Y., 1879, is from a fragment out of the Hamilton shales. We infer, therefore, that examples of this species which have come into the possession of the State survey have been not only rare but very poorly preserved. I have found many individuals in a very perfect state of preservation which agree, as far as may be, with Mr. Hall's description of this species. As the description of the species has been from fragmentary specimens, it is difficult for me to pronounce definitely on the identity of the very abundant examples of my own with those of Mr. Hall, but the probabilities are quite in favor of it, as I find a close agreement between the description, as far as it goes, and my specimens. Hall, in the final report on the Devonian Gastropoda, has also described a more perfect example of the genus, very similar in its features, as shown both in the illustration, Plate XXVI, Fig. 14, and in the description to *B. natator*, which he has called *B. explanatus*. This is from an uncertain horizon, probably that of the Hamilton shales, and it may be represented among the specimens from the Naples shales, but on account of its greater size and more explanate stoma, it is necessary to regard the majority of the *Bellerophа* of these shales as *B. natator*, a species common in all the outcrops of the lower fossiliferous beds.

27. Bellerophon incisus, n. sp.

Among my specimens of this genus from Parish Gully in Naples I find one which is distinctly different from the described species in these particulars: Fine, distant, incised, revolving lines appear on the shell at the beginning of the last volution, and pass outward, being nearly parallel for most of the distance, and become obsolete only near the margin of the shell. The dorsum is well marked from the stoma to the most elevated portion of the whorl, where it becomes obsolete. The dorsum is quite smooth, showing no trace of the retrally curving lines of growth. On either side of the dorsum on the most elevated portion of the shell are from thirteen to fifteen of the incised lines. Edge of stoma somewhat emarginate at the dorsum. No concentric striæ, but a few low, irregular concentric ridges. In its general proportions the species resembles *B. explanatus* H.

Genus EUOMPHALUS.

28. Euomphalus planodiscus.

Euomphalus planodiscus Hall, 1860, Thirteenth Ann. Rep. N. Y. State Cab. Nat. Hist., p. 109; 1879, Pal. N. Y., Vol. V, Pt. II, p. 57, Pl. XVI, Figs. 1-4.

This species was described from the Marcellus shales, and has hitherto been regarded as limited to that horizon. I have found it to be quite common in the calcareous concretions of Briggs' Gully.

Genus PLEUROTOMARIA.

29. Pleurotomaria capillaria.

Pleurotomaria capillaria Conrad, 1842, Jour. Acad. Nat. Sci., Vol. VIII, p. 271, Pl. XVI, Fig. 11; 1879, Pal. N. Y., Vol. V, Pt. II, p. 77, Pl. XX, Figs. 18-21.

This species constitutes a prominent member of the gastropod fauna of the Hamilton shales, and it has been found in several examples by Mr. Luther in the Naples shales. I do not know of its occurrence in the Genesee shales except in the upper portion or transition beds. Thence it ranges upward through the lower fossiliferous beds of the Naples shales and into the flag-stones of the higher strata.

Genus TROCHUS.

Subgenus PALÆOTROCHUS.

Trochus subgenus *Palæotrochus* Hall, 1879, Pal. N. Y., Vol. V, Pt. II, p. 133, Pl. XXX, Fig. 14.

"Shell conical, trochiform; spire elevated; volutions moderately convex; aperture transverse; columella?"

The above name was proposed to include a single species, *Pleurotomaria Kearneyi* Hall, from the Upper Helderberg, of which Mr. Hall has said: "I see no reasons why it should not be embraced in the Linnean genus Trochus and have proposed for it the subgeneric name."

From the shales at Naples I have several specimens which agree in all but a single particular with the species described by d'Archiac and de Verneuil as *Monodonta purpurea* (*Littorina purpurea* Sandberger) from Paffrath. In general contour, sculpture, form of the stoma, and excavation of the inner lip, they are similar, but the European species bears upon the inner lip a strong callosity which does not appear in my specimens. Although there is a wide difference in the external features of *P. Kearneyi* and my examples, there is a close agreement in all generic features. With *Ptychomphalus* and *Portlockia* of de Koninck it agrees in the form of its stoma and inner lip, but it has not in common with these genera anything that can be regarded as a Pleurotomaria band. Although agreeing well with *Paleotrochus*, it is difficult to point out a singular particular in which it does not coincide with living representatives of the genus Trochus.

30. Trochus (Palæotrochus) præcursor, n. sp.

(Plate III, Figs. 6-9.)

Volutions, five. The last whorl making threee-fourths the height of the shell. Distance from apex to stoma, 13^{mm}; width across the body-whorl, 13^{mm}. Whorls ventricose, depressed at the sutures. Body-whorl depressed below, with a tubercled carina passing about it two-thirds the distance from the suture. Stoma transverse, subtriangular. Outer lip simple. Inner lip without callosity. Columella with a spirally-striated excavated band, which becomes obsolete as it passes downward. Surface marked by prominent tubercles arranged regularly in spiral lines. Of these lines of tubercles, two at or near the carina are the most strongly developed, and the interval between them greater than that between any other two lines. Of these spiral rows on the body-whorl generally eight are above and seven below the carina, and are increased by intercalation. The interspaces between the tubercles show very fine, transverse linings, only to be seen with a glass.

Genus PLATYOSTOMA.

31. Platyostoma (?) minutissimum, n. sp.

I find in the concretionary layers in Parrish Gully and along Honeoye Lake a remarkable abundance of a minute shell which I temporarily refer to this genus. These measure across the body-whorl from $\frac{1}{2}$ to 1^{mm} and are $\frac{3}{4}^{mm}$ high. The volutions are three in number, the last very large and ventricose; surface without any visible ornamentation. That this is the young of some gastropod is quite possible, but as there is no species of gastropod that I know from this horizon of which this could be the young form, I venture to regard it as a new species. The individuals are so abundant in places that one may count scores over a single square inch of the surface of the rock. The sections of the rock for the microscope usually give abundant evidence of them.

Genus LOXONEMA.

32. Loxonema Noe, n. sp.

(Plate III. Fig. 10.)

Among the specimens from the concretions of Briggs' Gully and Parrish Gully and occasionally from the soft underlying shales, is a small *Loxonema* measuring from 5 to 8^{mm} in length. This is the only representative of the genus I know from this horizon, and it is quite distinct from the *Loxonemas* of the Hamilton and Chemung faunas in the proportionally large and few ribs on the whorls.

PTEROPODA.

Genus HYOLITHES.

33. Hyolithes Neapolis, n. sp.

(Plate III, Figs. 4 and 5.)

Length of the shell on dorsal side, 23mm; width across stoma, 8mm; ventral side, ½ to 1mm longer than the dorsal, projecting above the dorsal margin of the stoma; dorsal side often showing two depressed furrows passing from apex to stoma, which are usually much increased in strength by compression. Also marked by strong transverse striations, which are especially prominent on the central, most convex portion of the shell, where they become strong *rugæ*. Toward. the margins these markings become obsolete. No longitudinal sculpture. The ventral margin of the stoma is rounded, and the surface of the ventral side is marked by concentric transverse lines of growth all running parallel to the stoma. No longitudinal markings. This is a very handsome species, distinct from the species of *Hyolithes* in the adjoining faunas of the Chemung and Hamilton in the character of its sculpture. It occurs, as far as known only in the softer, lower shales. From the black shales of the upper black band in Parrish Gully I have two fragments, which bear, one a dorsal valve and one a ventral valve of a very small individual, measuring 4½mm in length, which lack the characteristic sculpture of *H. Neapolis* and belong probably to another species, although the condition of their preservation is not such as to allow their description.

Genus COLEOLUS.

34. Coleolus aciculum.

Orthoceras aciculum Hall, 1843, Geol. N. Y., Survey Fourth Geol. Dist., p. 243.
Coleolus aciculum Hall, 1879, Pal. N. Y., Vol. V, Pt. II, p. 187.

Abundant everywhere throughout the lower shales, associated with *Goniatites complanatus* and *Cardiola retrostriata*. I have had occasion to doubt somewhat the value of Hall's reference of this, originally regarded as an *Orthoceras*, to this genus. I have not infrequently collected specimens showing evidence of septa, these especially common in the concretions of Honeoye Lake, and which in external peculiarities agree very perfectly with the description of *Coleolus aciculum*. I have not seen the siphuncle to any of these individuals, and it may be possible that this genus includes septiferous forms. Though this does not appear from the diagnosis of it, the original figure of *Orthoceras aciculum* in the Report on the Fourth District of New York shows the presence of septa, and, as the genus stands now, may be regarded as representing a specimen of my species *O. aciculoides*. As I have already remarked, under the description of that species, many of the forms occurring in the Naples shales which have usually been referred to *O. aciculum* may have to be referred to *O. aciculoides*, and other septa-bearing forms must remain for the present without definite reference, as material is not at hand for study.

Genus STYLIOLA.

35. Styliola (Styliolina) fissurella.

Tentaculites fissurella Hall, 1843, Geol. N. Y., Survey Fourth Geol. Dist.; not *T. fissurella* Hall, Ills. Dev. Fossils, Pl. XXV, Figs. 12–14.

Styliola fissurella Hall, 1879, Pal. N. Y., Vol. V, Pt. II.

As already noticed, this minute pteropod is very abundant in the Naples shales, making a very large element of the calcareous matter of the Parrish Gully concretionary layer. In the shaly layers it is much less abundant, but will be found in many of the higher sandy shales and flagstones.

Karpinsky (Die fossilen Pteropoden am Ostabhange des Urals—Mém. de l'Acad. St. Petersburg, 7th ser., T. XXXII, No. 1, 1884) has suggested the probability that the paleozoic Styliolæ are generically different from the living members of the genus, and proposes the name *Styliolina* for the former. *Styliolina* is distinguished from *Styliola* by the form of the embryonal bulb, the lack of longitudinal furrows and thorn-like processes about the stoma, and the presence of longitudinal incised lines.

Genus TENTACULITES.

36. Tentaculites gracilistriatus.

Tentaculites fissurella Hall, 1876, Illus. Devonian Fossils; not *T. fissurella* Hall, 1843, Geol. N. Y., Survey Fourth Geol. Dist.

Tentaculites gracilistriatus Hall, 1879, Pal. N. Y., Vol. V, Pt. II, p. 173, Pl. XXXI, Fgs. 12, 13; Pl. XXXI A, Figs. 37–47.

This species, quoted by its author from the Marcellus and Hamilton shales, I have found not uncommonly associated with the foregoing.

Tentaculites gracilistriatus is regarded by Karpinsky in the work cited above as a synonym for *T. acuarius* Richter.

PELECYPODA.

Genus CARDIOLA.

37. Cardiola retrostriata.

Cardiola retrostriata von Buch.

Venericardium retrostriatum von Buch. Ueber die Ammoniten, p. 50.

Cardium palmatum Goldfuss, Petrefacta-Germaniæ, p. 270, Pl. XXXIII, Figs. 8–10.

Cardiola retrostriata Keyserling, 1846, Eine Reise in das Petschoraland, p. 254, Pl. XI, Fig. 3.

Avicula speciosa Hall, 1843, Geol. N. Y., Survey Fourth Geol. Dist.

Cardiola speciosa Hall, Miller, 1877, Am. Pal. Fossils, p. 186.

Cardiola speciosa Hall, 1883, Pal. N. Y., Vol. V, Pt. I; Plates and Explanations, Pl. LXX, Figs. 2–9.

Mr. Hall described and figured in 1843 (*loc. cit.*) the species *Avicula speciosa*, and has more fully illustrated the same under the name *Cardiola speciosa* in his late work, Plates and Explanations of the Devonian Lamellibranchs of the State of New York, the entire text of which has not appeared at the present writing. There is much variation in the form of this species, as it occurs in the Naples shales. It is here the most abundant fossil in the group (excepting *Styliola fissurella*), and the hundreds of specimens which have passed through my hands show the nature of the variation to be thus: The outline of the shell is most commonly approximately circular, sometimes becoming transverse. In the circular forms the shell is more elevated at the beak than in the more transverse individuals. The variation in this respect is, however, slight, and only to be perceived in specimens from the calcareous concretions, where the form has been well preserved. The variation in size is from 2 to 8^{mm} in length in the commonly occurring individuals, averaging about 5^{mm}. The surface is marked in the normal form by eight or nine ribs, between which lie comparatively deep *sulci*. Rarely the ribs become as many as twelve or fifteen. They are crossed by closely oppressed, retrally-bent lines, in which the retral bend is sometimes an even arc, and sometimes sharply angulated at the middle. Not infrequently each of these ribs is bordered by a fine elevated margin, which limits the ends of the retral striæ. Many of these features are very well brought out in Hall's illustrations of *Cardiola speciosa* in the place cited, but he has not noticed the forms with the elevated margin to the ribs. I have compared *C. speciosa* Hall, with specimens of *C. retrostriata*, v. Buch, from the Middle and Upper Devonian [illegible]ltenau, Bicken, Adorf, Bredelar, and elsewhere, and to my [illegible] is *absolutely* no specific difference in the American and [illegible]ecies.

ıe European species varies within even wider limits than the Americ as is well shown in the illustrations given by the Sandbergers,[34] re the three varieties represented do not any of them compare favor- with the most common American forms. By an error (*op. cit.*, p. 270) variety there mentioned as *Cardiola retrostriata* var. *typus*, repre- s var. *angulifera*, and no illustration of the typical form is given. *typical* form, that is, the one most usually occurring in the Upper onian horizons, is well illustrated by Goldfuss (*loc. cit.*), Keyserling *cit.*), and Roemer.[35] This form bears from eight to ten, sometimes ve, ribs, and its sculpture is the same as in *C. speciosa*. F. A. Roemer[36] given a figure of *Cardium palmatum* Goldfuss, which is rather more sverse than the usual American forms, and bears twelve ribs; this sverse form is, however to be found in the Naples shales associ- with the others. *Cardiola retrostriata* v. Buch is a shell of very distribution throughout the Upper and Middle Devonian of Eu- Keyserling[37] has described it from the Domanik Schiefer of Pets- a Land; F. A. Roemer[38] from the same horizon (Mittel Oberdevon, manik Schiefer" Credner, 1883) of Altenau in the Ober Harz. It erywhere abundant in the same horizon throughout Westphalia, ıe Fichtel Gebirge, etc. In the north of France and on the Belgian tier the "Schistes à Cardium palmatum" are a member of the Up- Devonian, and are assigned the following position by Gosselet[39] in classification of the Upper Devonian beds.

sammites du Condroz, Calcaire d'Œtræungt Psammites.

histes de Famenne {
Schistes de Famenne, proprement dits.
Schistes à Cardium palmatum.
Calcaires de Trelon.
Cuboides Beds.

he relation of this horizon for *Cardiola retrostriata* and its American zon will be well seen in the following list of the most characteristic ils of the formations lying in immediate juxtaposition to the histes à Cardium palmatum." This is quoted from a section be- en Marienbourg and Frasnes, given by Gosselet. (*Loc. cit.*)

histes de Famenne:

Rhynchonella cuboides: Hamilton group.
R. pugnus: Chemung sandstones.
Spirigera concentrica: Hamilton group.
Spirifera disjuncta: Chemung sandstones.
S. euryglossus.
S. Murchisoniana.
Productus subaculeatus: Chemung sandstones.

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[34] Verstein. des Rhein. Schichten-Syst., Pl. XXVIII, Figs. 8, 9, 10.

[35] Lethæa Palæozoica, Taf. XXXV, Fig. 16.

[36] Beitr. zur Kenntn. d. Nordw. Harz, Taf. IV, Fig. 11.

[37] *Loc. cit.*

[38] Beitr. z. geol. Kennt. d. Nordw. Harz, Taf. IV, Fig. 11.

[39] Annales d. Mines, Ser. 6, Tom. XII, p. 595, 1867.

2. *Schistes à Cardium palmatum:* (*Cardiola retrostriata*); *Naples shales.*
   Goniatites retrorsus: Naples shales.
   Rhynchonella bijugata.
3. *Schistes à nodules argilo-calcaires* (*Calcaires de Trelon*):
   Rhynchonella cuboides: Hamilton group.
   Atrypa reticularis: Hamilton group.
   Rhynchonella bijugata.
   Spirifera euryglossus.

The species of these higher Devonian beds have been subject to much greater *recurrence* in Europe than in America, as was early noticed by Bigsby.[40] *Rhynchonella cuboides* Sowerby, is fairly diagnostic of the lower Upper-Devonian and the American species after its type, *R. venustula* Hall, originally identified as *R. cuboides* by Conrad, which occurs only, as far as known, in the Tully limestone, at the base of the Genesee shales, is strong evidence of approximate parallelism of the Tully limestone and the European beds containing *R. cuboides*, viz., the Eifel cuboides kalk, the Aix-la-Chapelle cuboides schichten, the Iberger kalk of the Harz Mountains, etc.

Rhynchonella pugnus Sowerby, which ranges into lower horizons in Great Britain and Europe than America, is to be regarded as an Upper Devonian or Lower Carboniferous type, and in the section given it occurs in its normal position in association with *Spirifera disjuncta* Sowerby (*S. Verneuili*), a brachiopod distinctly upper Upper-Devonian in its type and in America *exclusively* so in its species, but which in Belgium, France, and the Rhineland ranges below its normal horizon into the cuboides beds. *Productus subaculeatus* Murchison is in Europe an Upper Devonian fossil, ranging occasionally into the Middle Devonian. In New York, Hall has identified it from the Corniferous limestone or Lower Devonian, but, according to Bigsby, de Verneuil has mentioned two species very similar to *P. subaculeatus*, collected by Lyell from Tioga. If by this Tioga County, New York, is meant, it would be within a district of Chemung outcrops. The "Schistes à *Cardium palmatum*" are described by Gosselet as black or violet-black, fissile shales, and are very like the bituminous beds of the Genesee and Naples shales.

Cardiola retrostriata is also quoted[41] from the shales of Torbay, in Devonshire, with *Goniatites retrorsus*, *Bactrites Schlotheimii*, and *Pleurotomaria turbinea*, which Lee regards an Upper Devonian horizon. Leonhard[42] has mentioned the species from Novaja Semlia. But the species is not confined to Upper Devonian horizons. Bigsby[43] quotes it from the Middle Devonian "*Calcaire de Givet.*" Maurer[44] refers to this species a form from the *Wissenbach slates* of the Ruppbachthal, Lower Devonian. Von Seebach has mentioned it from the *Wissenbach* (*Goslar*)

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[40] Quar. Jour. Geol. Soc., Vol. XIV, 1858.

[41] Lee, Geol. Mag. new ser., Vol. IV, p. 100, 1877.

[42] Ueb. paläoz: Gebilde im Nord-Deutschl. u. Belg., 1844, p. 139.

[43] Thesaurus Devonico-Carboniferus, p. 166.

[44] Neues Jahrbuch, 1876, p. 808.

shales of the Harz, that is, lower Upper Devonian. Barrois[45] has found Sandberger's var. *angulifera* in the "Schistes de Porsguen" of La Rade de Brest, which he refers to the Lower Devonian. It also occurs in the Bohemian Upper Silurian, *Étages E.* and *H.* In America its vertical range is much more limited. I have the species from the Hamilton shales of Hopewell, Ontario County, and a single specimen from the bituminous Marcellus shales, giving thus the species a range from the base of the Middle Devonian to the base of the Chemung group proper.

Genus CARDIOLA.

38. Cardiola Doris.

Cardiola Doris Hall, 1883, Pal. N. Y., Vol. V, Pt. I. Plates and Explanations, Pl. LXX, Figs. 10, 11.

A rather rare species, associated with *Lunulicardium ornatum* and *L. acutirostrum.* From Parrish Gully.

Genus CARDIOMORPHA.

39. Cardiomorpha suborbicularis.

Myalina suborbicularis Hall, 1843, Geol. N. Y., Survey Fourth Geol. Dist., p. 243.

Cardiomorpha suborbicularis Hall, 1877, Miller, Am. Pal. Foss., p. 186. 1883, Hall, Pal. N. Y., Vol. V, Pt. I. Plates and Explanations, Pl. LXIII, Figs. 9, 10. Not C. *suborbicularis* Sandberger.

This is a very abundant species in the lower shales, and very strongly suggests *Cardiola concentrica* v. Buch, of the lower Upper-Devonian of Westphalia and the Harz.

Genus LUNULICARDIUM.

40. Lunulicardium ornatum.

Lunulicardium ornatum Hall. *Pinnopsis ornata* Hall, 1843, Geol. N. Y., Survey Fourth Geol. Dist., p. 244.

Lunulicardium ornatum Hall, 1877, Miller, Am. Pal. Foss., p. 193. 1883, Hall, Pal. N. Y., Vol. V, Pt. I. Plates and Explanations, Pl. LXXI, Figs. 25–29.

A characteristic species, occurring first in the lowest green shales of the group at Cook's Point, on Canandaigua Lake, and in the beds immediately underlying the lower black band in Snyder's Gully, south from Woodville.

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[45] Annales de la Soc. Geol. du Nord., Tom. IV, p. 89, 1877.

41. Lunulicardium acutirostrum.

Pinnopsis acutirostra Hall, 1843, Geol. N. Y., Survey Fourth Geol. Dist., p. 244.

Lunulicardium acutirostrum Hall, 1877, Miller, Am. Pal. Fossils, p. 193. 1883, Hall, Pal. N. Y., Vol. V, Pt. I. Plates and Explanations, Pl. LXXI, Figs. 30–32.

Not uncommon in the soft shales of Parrish Gully, Briggs' Gully, and elsewhere.

42. Lunulicardium fragile.

Avicula fragilis Hall, 1843, Geol. N. Y., Survey Fourth Geol. Dist., p. 222.

Aviculopecten fragilis Hall, 1877, Miller, Am. Pal. Fossils, p. 184.

Lunulicardium fragilis Hall, Am. Pal. Fossils, p. 193.

L. fragile Hall, 1883, Pal. N. Y., Vol. V, Pt. I. Plates and Explanations, Pl. LXXI, Figs. 1–14.

A characteristic and abundant fossil in the Genesee shales, losing its abundance with the close of the "transition shales," and to be found but sparingly in the Naples beds. My specimens are from Parrish Gully.

BRACHIOPODA.

Genus LINGULA.

43. Lingula ligea.

Lingula ligea Hall, 1860, Thirteenth Ann. Rep. N. Y. State Cab. Nat. Hist.

L. ligea var. Hall, 1867, Pal. N. Y., Vol. IV, Pl. II, Fig. 8, p. 8.

I have of this species but two individuals, one from the soft shales of Cashaqua Creek, Livingston County, and the other from the higher sandy shales at Naples. Mr. Hall's specimens are quoted from the arenaceous layers of the group.

44. Lingula triquetra, n. sp.

(Plate III, Fig. 11.)

Shell comparatively large, broadly spatulate, the sides sloping away very evenly from the apex at an angle of about 50 degrees, and rounding somewhat abruptly to the anterior margin, which is very transverse. In the ventral valve the apical angle is more acute than in the dorsal, projecting slightly over the dorsal apex; the width of the shell on the anterior margin nearly equal to three-fourths the length of dorsal valve. The surface is ornamented by concentric ridge-like lines of growth, which are not all of the same size. No evidence of radiating, decussating lines. Length of dorsal valve, 18^{mm}; greatest width, 13^{mm}; length of ventral valve, $19\frac{1}{2}^{mm}$. This species resembles somewhat *L. læna* H.

and *L. palæformis* H. of the Hamilton shales, but differs from the former in being shorter, more transverse on the anterior margin, and with straighter sides, and from the latter in its relatively less width anteriorly, more abrupt anterior marginal angles, and the absence of radiating striæ.

BRYOZOA.

Genus AULOPORA.

45. Aulopora annectens, n. sp.

(Plate III, Fig. 15.)

A single specimen of this species attached to a valve of *Lunulicardium ornatum* has a creeping polyzoarium, polyp-cells scattered at nearly equal intervals along it. The sclerenchyma is flattened and the polyp-cells evenly sessile, opening directly from the base of the polyzoarium. Polyp-cells shallow, and with a number of deep striations on the inner surface, making pseudosepta. This is from the sandy layers in the lower beds of the group on Whale's Back, Canandaigua Lake.

CRINOIDEA.

Genus MELOCRINUS.

46. Melocrinus Clarkei.

Melocrinus Clarkei H. S. Williams, 1882, New Crinoids from Rocks of Chemung Period., Proc. Acad. Nat. Sci., Phila., p. 31.

This species has been found by Mr. Luther in the shales of Hatch Hill, Naples, occurring in the same manner as in the Genesee strata, a single thin layer, which is a mass of calices and columns. It is the only crinoid yet known from this group in Ontario County.

PLANTÆ.

Genus LEPIDODENDRON.

47. Lepidodendron primævum.

Lepidodendron primævum Rogers, 1858, Geol. Survey of Pennsylvania, Vol. II, Pt. II, p. 828.

Specimens referable to this species occur commonly in the upper bituminous layers in Naples and in the township of Sparta, Livingston County. Usually they are in a poorly preserved, decorticated "Knorria" condition. Outside of these bituminous strata the species is of rare occurrence. A specimen very remarkable for its size and beauty of preservation has been found by Mr. Luther in the upper sandy shales of the group at the opening of Grimes's Gully, in Naples. This is a long trunk, measuring along the flattened edge 70^{mm} in width. When found only this transverse edge was exposed, and the trunk ran directly back into a thick bed of compact shales, so that it became necessary to remove several hundred cubic feet of this rock in order to expose it. Already a length of 225^{cm} has been worked out, the diameter of the flattened trunk constantly increasing the further the rock has been penetrated, and it measured 130^{mm} in section at the spot where it was necessary to break it off on account of the enormous mass of rock overlying. I trust that soon the remainder of this remarkable specimen may be uncovered, and believe that we may eventually find the root attached.

48. Lepidodendron gaspianum.

Lepidodendron gaspianum Dawson, 1860, Canadian Naturalist and Geologist, Vol. V.

Good specimens referable to this species are to be found in the higher sandy shales of the Tannery Gully, in Naples.

Genus CYCLOSTIGMA.

49. Cyclostigma affine.

Cyclostigma affine Dawson, 1881, Quar. Jour. Geol. Soc., Vol. XXXVII.

This species, which was founded on specimens taken from the horizon of the Naples shales in the adjoining county of Yates, I have found in the bituminous beds in Sparta. The specimens have been identified by Dr. Dawson as belonging to this species.

Genus FUCOIDES.

50. Fucoides graphica.

Fucoides graphica Vanuxem, 1842. Geol. N. Y., Survey Third Geol. Dist., p. 172.

This paradoxical fossil occurs very widely distributed throughout the flagstones of the group, always as long, low, oval elevations on the under surfaces of the slabs, a fact which proves that whatever the nature of the fossil may be it represents only the fillings of depressions on the originally muddy sea-bottom. These may have been formed by the wallowing of some animal, or by the decomposition of sea-weed over the bottom, but it is impossible yet to decide their true origin, as they have not been sufficiently investigated.

A number of other species have been described from the rocks of this age in New York State by Conrad, Hall, Dawson, and Williams, which I have not as yet been able to find in the district under consideration. Some of these cannot be identified on account of lack of completeness in the original definition of the species. This is especially true of the Pelecypoda, of which I have a large number of unidentified forms, any description of which I feel obliged to defer, as Mr. Hall's study of these fossils is just issuing from the press, and probably any descriptions of mine would increase the unfortunate confusion which has hitherto existed in regard to the New York Devonian Pelecypoda.

The following species must be added to complete the list of the known fauna of these rocks:

Gomphoceras Ajax Hall.
1879, Pal. N. Y., Vol. V, Pt. II, p. 350, Pl. XCIV, Fig. 8.

This species was described from the shales of the Portage group, at Penn Yan, N. Y.

Orthoceras Thyestes Hall.
1879, Pal. N. Y., Vol. V, p. 306., Pl. LXXXVIII, Fig. 2.

An exceptionally large and robust species "from the soft shales of the Portage group, near Watkins," Yates County.

Orthoceras Atreus Hall.
1879, Pal. N. Y., Vol. V, p. 305, Pl. LXXXVIII, Fig. 1, and Pl. LXXXIX, Figs. 10, 11.

Another extremely robust species quoted from the "Calcareous layers of the Portage group, at Penn Yan," Yates County, and from near Portageville on the Genesee River.

Conularia congregata Hall.
1876, Illus. of Devonian Fossils, Pl. XXVIII, Fig. 1.
1879, Pal. N. Y., Vol. V, Pt. II, p. 214, Pl. XXXIV, Fig. 1; Pl. XXXIV*a*, Figs. 9, 10, 11.

This is cited "from the shales of the Portage group, near Ithaca, N. Y."

Avicula triradiata Conrad.
1842, Vanuxem, Geol. N. Y., Survey Third Geol. Dist.

Not mentioned by Hall in his final report on the Aviculidæ, 1884.

Lucina retusa Hall.
Nucula lineolata Hall.
Astarte subtextilis Hall.
1843, Geol. N. Y., Survey Fourth Geol. Dist., p. 245.

These species, early described by Hall, do not appear in his recent monograph of the Devonian Pelecypoda.

Cardiomorpha undulata Hall.
1883, Pal. N. Y., Vol V, Pt. I. Plates and Explanations, Pl. LXIII, Fig. 16.

Cardiomorpha textilis Hall.
1883, Pal. N. Y., Vol. V, Pt. I. Plates and Explanations Pl. LXIII, Figs. 11-15.

Præcardium vetustum Hall.
1883, Pal. N. Y., Vol. V, Pt. I. Plates and Explanations, Pl. LXX, Figs. 18-20.

I have not had opportunity of comparing these figures with my specimens.

Orthis tenuistriata Hall.
1882, Geol. N. Y., Survey Fourth Geol. Dist., p. 246.

No mention has been made of this fossil in Hall's monograph of the New York Devonian Brachiopoda, and it is hardly to be regarded as a member of this fauna.

Spirifera lævis Hall.
Delthyris lævis Hall.
1843, Geol. N. Y., Survey Fourth Geol. Dist., p. 245.

Spirifera lævis Hall.
1867, Pal. N. Y., Vol. IV, Pl. XXXIX, p. 239.

This species, which is not uncommon in localities east of Ontario County, seems limited to those beds. I do not know of its occurrence west of Tompkins County.

Crania centralis Hall.
1879, Pal. N. Y., Vol. V, Pt. II, Pl. LXXXVIII, Fig. 2, under explanation of the figure of *Orthoceras Thyestes.*

Cyathocrinus ornatissimus Hall.
1843, Geol. N. Y., Survey Fourth Geol. Dist., p. 247.

The individuals upon which this species was founded were taken from the Portage shales at Portland, on Lake Erie. I have no knowledge of its having been found in any other locality, and the species has never as yet been carefully diagnosed.

Poteriocrinus (Decadocrinus) Zethus Williams.
Taxocrinus Ithacensis Williams.
Taxocrinus curtus Williams.
1882, New Crinoids from the Chemung group of New York.

These three species, described by Dr. Williams, from the vicinity of Ithaca, I have not as yet found.

Ormoxylon Erianum Dawson.
1871, Fossil Plants of Silur. and Dev. of Canada.

Asteropteris Novoboracensis Dawson.
1881, Quar. Jour. Geol. Soc., Vol. XXXVII, p. 299, Pl. XII, Figs. 1-9.

Equisetides Wrightiana[46] Dawson.
1881, Quar. Jour. Geol. Soc., Vol. XXXVII, p. 301, Pl. XII, Fig. 10; Pl. XIII, Fg. 20.

The last two of these species were described from specimens found in the adjoining county of Yates.

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[46] In the Geological Magazine for September, 1884, T. R. Jones and H. Woodward, regarding the original of this species as the abdominal segments of a Phyllopod crustacean, have thus described it, under the name *Echinocaris Wrightiana.* If this is correctly referred the original animal must have been of colossal dimensions.

THE PETROGRAPHIC AND PALEONTOLOGIC CHARACTERS OF THE PORTAGE BEDS.

TYPICAL EXPOSURES.

1. In the town of Naples, the Grimes and Cannery Gullies; on Hatch Hill; on the Garlinghouse road, and at Ingleside.
2. In the town of Italy, Yates County, the Clark Gully.
3. At Dansville, Livingston County.
4. On the Genesee River at Portageville.

From the highest horizon referred to the preceding group of shales, rise about 600 feet of heavy bedded gray and greenish sandstones, with some flagstones near their base, and occasional interlaminations of arenaceous shales. These were originally grouped with the Cashaqua and Gardeau divisions of Hall, as has already been noticed, under the name Portage group, and it may be that this was done more on negative than positive evidence, as these sandy layers are very barren of all organic remains. The paleontological connection between these Portage sandstones and the underlying Naples shales is very slight, and between the two must be drawn the line which separates the fauna of the Hamilton period from that of the Chemung. The original description of Hall characterized these sandstones by the abundance of the worm-borings *Scolithus* (*Fucoides*) *verticalis*, and these I have found to be quite abundant, especially at the top of the series and immediately underlying the beds bearing the important High Point Fauna presently to be noticed more at length. At Ingleside, in the township of Naples, I have found in these sandstones *Dictyophyton tuberosum* H., a fossil referred to the Hexactinellid sponges by Hall,[47] Whitfield,[48] Barrois,[49] and to the Algæ by Roemer;[50] also, *Ambocœlia umbonata* Conrad; these about 500 feet below the summit of the group on High Point, 3 miles west of the village of Naples. *Dictyophyton tuberosum* I have also found within 300 feet of the upper limit mentioned. This fossil must be regarded as characteristic of the Chemung fauna, as it is not known to occur outside of Chemung horizons.

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[47] Thirty-fifth Ann. Rep. N. Y. State Mus. Nat. Hist., 1883.

[48] Am. Jour. Sci., Vol. XXII, July and Aug., 1881.

[49] "Dictyospongidæ des Psammites du Condroz," Annales de l. Soc. Geol. du Nord, Tom. XI, 1883.

[50] "Bemerk. ueb. Hall's Gattung *Dictyophyton*." Sitzungsber. der schlesisch. Gesell. für vaterländ. Cultur, 1883.

Ambocœlia umbonata is also a characteristic and abundant Chemung fossil, though it occurs as a member of the Hamilton fauna, 1,000 feet below. In the sandstones and flags of Grimes's Gully, in Naples, at a distance of about 600 feet below the High Point horizon, I have found the Chemung fossils *Leiorhynchus mesacostalis* H. and (?) *Discina Leoni* H. Besides these, Mr. Luther has more lately detected *Ambocœlia umbonata* Con., *Atrypa aspera* H., *Stenochisma eximium* H., and some unidentified species of *Productella*. Below this fossiliferous stratum and within 10 feet of it are beds containing the characteristic species of the Naples shales, viz., *Cardiola retrostriata*, *Goniatites complanatus*, *Colеolus aciculum*. Further than the six species mentioned, all of which are characteristic of the typical fauna of the Chemung, I know of no other fossils from these Portage sandstones, with the exception of the crustacean species described by myself, viz., *Spathiocaris Emersoni*, *Dipterocaris Procne*, *D. pennæ-Dædali*, from the beds in the town of Canadice, and *D. pes-cervæ* from Dansville, Livingston County. There are thus ten well-defined fossils (exclusive of *Fucoides graphica* and *Scolithus verticalis*) which constitute the known fauna of the Portage sandstones, two of which, namely *D. pennæ-Dædali* and *D. pes-cervæ* may be peculiar to it; seven belong to the Chemung fauna above, namely, *Dipterocaris Procne*, *Ambocœlia umbonata*, *Atrypa aspera*, *Leiorhynchus mesacostalis*, *Stenochisma eximium*, (?) *Discina Leoni*, *Dictyophyton tuberosum*, and one comes over from the Naples fauna below, namely, *Spathiocaris Emersoni*.

The following table gives a list of all the fossils now known to occur in the Genesee and Naples beds in New York, and shows what portion of these faunas and floras have been derived from the rocks below of the Hamilton Period and what members pass upwards into the rocks of the Chemung Period. It therefore affords the evidence upon which the Naples shales and the Portage beds must be assigned to their appropriate horizons.

As a result of these investigations the fauna and flora of the old Cashaqua and Gardeau beds, *i. e.*, the Naples shales, are increased by 32 species or 50 per cent. (for Ontario and adjoining counties, 66 per cent.), and of the Genesee shales the list is increased by 27 species or 48 per cent. of the known fossils of these rocks occurring in the State, and 60 per cent. of the known contents of the rocks in Ontario County and vicinity.

A list of the fossils occurring in the Genesee, Naples, and Portage beds of Ontario County, with the names of species heretofore identified from these horizons elsewhere in the State of New York, but not as yet known within this district.

Species.	Hamilton shales.	Genesee shales.	Naples shales.	Portage beds.	Chemung beds.
Polygnathus dubius Hinde	*	*	*		
nasutus Hinde		*			
princeps Hinde	*	*			
palmatus Hinde		*			
punctatus Hinde		*			
Prioniodus erraticus Hinde	*		*		
spicatus Hinde		*	*		
angulatus Hinde		*			
armatus Hinde		*			
acicularis Hinde		*			
Dinicthys Newberryi Clarke		*			
Pristacanthus vetustus Clarke			*		
Palæoniscus devonicus Clarke		*	*		
Acanthodes pristis Clarke			*		
Scolithus verticalis Hall ?			*		
Ceratiocaris longicaudus Hall		*		*	
simplex Clarke			*		
Beecheri Clarke			*		
Echinocaris Whitfieldi Clarke			*		
Wrightiana Dawson			*		
Spathiocaris Emersoni Clarke			*		
Dipterocaris pennæ-Dædali Clarke				*	
pes-cervæ Clarke				*	
Procne Clarke				*	
Beyrichia Dagon Clarke		*		*	*
Goniatites complanatus Hall	*	*	*		
var. perlatus Hall			*		
discoideus Hall	*	*	*		
uniangularis Hall			*		
Patersoni Hall		*	*		
bicostatus Hall			*		
sinuosus Hall			*		
Lutheri Clarke			*		
nodifer Clarke		*			
peracutus Hall			*		
Chemungensis Hall *var*			*		
Astarte Clarke		*			
Orthoceras pacator Hall		*	*		
aciculoides Clarke			*		
Ontario Clarke			*		
filosum Clarke			*		
Stebos Clarke		*			
Mephisto Clarke		*			
Asmodeus Clarke		*			
Thyestes Hall			*		
Atreus Hall			*		
Gomphoceras Ajax Hall			* ?		
Manes Hall		*			
Conularia congregata Hall			* ?		
Hyolithes Neapolis Clarke			*		
Coleolus aciculum Hall		*	*		
Tentaculites gracilistriatus Hall	*	*	*		
Styliola fissurella Hall	*	*	*		
Bellerophon natator Hall	*		*		
incisus Clarke	*		*		
striatus Ferussac and d'Orbigny		*			
Euomphalus planodiscus Hall			*		
Loxonema Noe Clarke			*		
Palaeotrochus praecursor Clarke			*		
Platyostoma minutissimum Clarke			*		
Belial Clarke		*			
Macrocheilus (?) *Moloch* Clarke		*			
Pleurotomaria capillaria Conrad	*		*		
rugulata Hall	*	*			
Itys var. tenuispira Hall		*			
Cardiola retrostriata v. Buch		*	*		
Doris Hall			*		
Cardiomorpha suborbicularis Hall			*		
undulata Hall			* ?		
textilis Hall			* ?		
Praecardium vetustum Hall			* ?		
Lunulicardium fragile Hall		*	*		
acutirostrum Hall			*		
ornatum Hall			*		
Modiomorpha (?) *Chemos* Clarke		*			

A list of the fossils occurring in the Genesee, Naples, and Portage beds, etc.—Continued.

Species.	Hamilton shales.	Genesee shales.	Naples shales.	Portage beds.	Chemung beds.
Spirifera lævis Hall			*?		
Belpheger Clarke		*			
Pluto Clarke		*			
Ambocoelia umbonata Conrad	*	*		*	*
Atrypa aspera Hall				*	*
Chonetes setigera Hall	*	*			*
lepida Hall	*	*			
Leiorhynchus quadricostatus Hall		*			
mesacostalis Hall				*	*
(?) *Hecate* Clarke		*			
Stenochisma eximium Hall				*	*
Crania centralis Hall			*?		
Discina truncata Hall		*			
Lodensis Hall		*			
Leoni Hall (?)				*	*
Lingula ligea Hall			*		
spatulata Hall		*			
concentrica Vanuxem	*	*			
triquetra Clarke			*		
Cyathocrinus ornatissimus Hall			*?		
Melocrinus Clarkei Williams		*	*		
Poteriocrinus Zethus Williams			*?		
Taxocrinus Ithacensis Williams			*?		
curtus Williams			*?		
Aulopora annectens Clarke			*		
Cladochonus sp		*			
Dictyophyton tuberosum Hall				*	*
Cyclostigma affine Dawson		*	*		
Asteropteris noveboracensis Dawson			*		
Ormoxylon Erianum Dawson			*		
Dadoxylon Clarkei Dawson		*			*
Cladoxylon mirabile Dawson		*			
Lepidodendron primævum Rogers		*	*		
Gaspianum Dawson		*	*		
Calamites inornatus Dawson		*			
Rachiopteris (Rhodea) pinnata Dawson		*?			
Fucoides graphica Vanuxem			*	*	
Sporangites Huronensis Dawson		*			

Thus of 47 species occurring in the Naples shales of this district, 15 species or 34 per cent. occur also in the fauna of the Genesee; 1 species (3 including *Fucoides graphica* and *Scolithus verticalis*) or 2.1 per cent. in the fauna of the Portage; 9 species or 19 per cent. in the fauna of the Hamilton proper.

Of 32 species (not including 11 species belonging to the pyrite fauna) here noted as occurring in the Genesee shales of the district, 16 species or 50 per cent. occur also in the fauna of the Naples shales; 11 species or 34 per cent. in the fauna of the Hamilton proper.

Of 12 species which here occur in the Portage beds, 1 (3 ?) species or 8.5 per cent. is found also in the Naples shales; 7 species or 60 per cent. occur in the overlying Chemung beds.

There are two conclusions to be drawn from these tables, namely, (1) that the Naples shales have no such paleontological relation to the rocks of the Chemung Period as to justify the union of them with these rocks; (2) that their fauna and flora is more closely allied to those of the Hamilton shales, and that therefore these beds are to be regarded either as constituting the uppermost member of the Hamilton Period, or, together with the Genesee shales, representing a distinct geological epoch.

From the facts (1) that only 10 of the 66 species which may be referred to the horizon of the Naples shales in New York, and 15 of the 56 species in the Genesee shales occur in the fauna of the Hamilton epoch, and (2) that as far as it is possible to trace a correspondence between these and transoceanic faunas they appear to belong to a lower Upper-Devonian horizon, and (3) that the transition from the Genesee to the Naples beds is so gradual petrographically and paleontologically that a very strong line of division between them is not possible, the more probable conclusion is that these two groups of strata represent the epoch of the lower Upper-Devonian in Western New York.

FAUNA OF CHEMUNG BEDS AT HIGH POINT.

Overlying the thick-bedded "sandstone with vertical fucoids," which was described by Mr. Hall as composing the terminal mass of the Portage sandstones, is a stratum 5 feet in thickness which contains a fauna of much interest. This was discovered in 1878 by Mr. D. D. Luther, on the summit of "High Point," a mountain standing 1,900 feet above the sea, and situated about 3 miles northwest of the village of Naples. The exposure of the stratum is quite limited, and, as it is *in situ* only on the sheer face of a high cliff, has been studied mostly from the fragments which have fallen into the talus below. I know as yet of no other outcrop of the stratum, although I have reason to believe that it will be found among the high hills lying to the south. The containing rock is a sandy limestone, or a sandstone, with a large intermixture of calcic carbonate brought in by the fossils it contains, and is in places largely composed of fragments of crinoid columns. It has afforded me the following fauna:

Rhynchonella pugnus Martin.
Atrypa aspera Hall.
A. reticularis Linnæus.
A. hystrix Hall.
Streptorhynchus Chemungensis Hall.
Spirifera disjuncta Sowerby.
S. subattenuata Hall.
S. mesacostalis Hall.
S. bimesialis Hall.
Ambocœlia umbonata Conrad.
Strophodonta Cayuta Hall.
S. variabilis Calvin.
S. exilis Calvin.
Productella speciosa Hall.
Orthis infera Calvin.
Chonetes setigera Hall.
Crania sp.
Pterinea sp.
Polypora sp.
Fenestella sp.
Zaphrentis sp.
Receptaculites sp.
Dadoxylon Clarkei Dawson.
Rhynchodus sp.
Cladodus sp., and other undetermined fish remains.

In the summer of 1882 I made Dr. H. S. Williams, of Ithaca, acquainted with the locality, and he has identified the following additional species:[51]

- *Productella dissimilis* Hall.
- *Orthis Iowensis* Hall.
- *Strophodonta arcuata* Hall.
- *S.* (*Strophonella*) *reversa* Hall.
- *S. Canace* Hall and Whitfield.
- *Spirifera Orestes* Hall and Whitfield.
- *Stenochisma contractum* Hall.
- *Fistulipora occidens* Hall and Whitfield.

Of this fauna only the following species had been previously recognized from the Chemung group of New York State:

- *Atrypa aspera* Hall.
- *A. reticularis* Linnæus.
- *A. hystrix* Hall.
- *Streptorhynchus Chemungensis* Hall.
- *Strophodonta Cayuta* Hall.
- *Spirifera mesacostalis* Hall.
- *S. disjuncta* Sowerby.
- *Productella speciosa* Hall.
- *Chonetes setigera* Hall.
- *Ambocœlia umbonata* Conrad.
- *Stenochisma contractum* Hall.

Rhynchonellæ very closely allied to *pugnus* Mart. have already been recognized in America by Meek[52] in the subcarboniferous rocks of Rockford, Indiana, and Chouteau Springs, Missouri, in forms which are closely comparable to the English and Irish carboniferous forms. These have been referred to the species *R. Missouriensis* Shumard.[53] Marcou, in 1858, and McChesney, in 1860, described species of quite the same type as *R. pugnus*, the former under the name *R. Rockymontana*, the latter with the name *R. eatoniaeformis*, from the carboniferous of Utah and Illinois respectively. Although *R. pugnus* belongs to a carboniferous type, and occurs abundantly in the English and Irish carboniferous rocks, it is also in the same countries a member of the fauna of the Middle Devonian.[54] It isa well-known fossil in the Rhenish Devonian[55] throughout the Stringocephalen Kalk and the Upper Calceola Schichten, but here it is not to be regarded as a diagnostic fossil, inasmuch as its more usual occurrence is at a higher horizon. Kayser,[56] Roemer, and Schlönbach quote it from the vicinity of Eschweiler and Aachen, where it is associated with *Spirifera disjuncta* at a horizon which parallellizes with the Lower Chemung of America. In Belgium and the north of France it is quoted by Bureau[57] from the Cop Choux limestone, associated with *Rhynchonella cuboides*, and by Gosselet[58] from the "Schistes de Famenne," in association with *S. disjuncta* and *R. cuboides*, both of which horizons agree, as nearly as we can expect agreement in so widely separated formations, with the Chemung group of New York.

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[51] Am. Jour. Sci., Vol. XXV, Feb., 1883.

Dr. Williams has somewhat forestalled my work upon this fauna by the publication of this article upon A remarkable Fauna at the base of the Chemung Group in New York, but my observations here indorse and materially strengthen the *essential* views there set forth.

[52] Geol. Survey of Illinois, 1866, Vol. II, p. 154.

[53] Geol. of Missouri, 2d Ann. Rep. 1855, p. 204, and Meek, Geol. Survey of Illinois, Vol. II, p. 153.

[54] Davidson, Mon. British Dev. Brach., p. 60.

[55] Maurer, Neues Jahrbuch, 1875; Kayser, Zeitschr. d. d. Geol. Gesell., Band XXIII.

The forms of this species occurring in the Rhenish and Harz Devonian show a variation from the typical forms of *R. pugnus* figured by Davidson, and this author has referred the examples figured by the brothers Sandberger to *R. acuminata* Martin. Nowhere, to my knowledge, does this species in any one Devonian fauna present so considerable a variation as the specimens from High Point. Certain individuals with only a medium elevation of the mesial fold and with lateral plications acute at the margin, becoming obsolete over the visceral regions, represent the type of *R. pugnus*. Others, with extremely acute and elevated anterior margin and only traces of one or two lateral plications, represent the varieties of *R. acuminata*, *mesogonia*, or *plicata* Phill.[59] *R. pugnus* is one of several Devonian species of cosmopolitan range, and it has from the time of its first appearance in the Middle Devonian of Germany to its disappearance in the Lower Carboniferous, adapted itself to the change in the probable westward migration of the Devonian fauna of Europe, and has as a specific type outlived, without much variation, most of its earlier associates.

Dr. Williams has compared the fauna represented in the second of the lists given above with a peculiar and interesting fauna originally described by Hall[60] from Lime Creek, near Rockford, Iowa, and subsequently reviewed by Dr. C. A. White.[61] By these two authors this fauna was regarded as belonging to the Hamilton group. Later Messrs. Hall and Whitfield[62] published a study of the same fauna, describing some additional species, and referred it to the Chemung group, and more lately Mr. S. Calvin[63] has reviewed the fauna and given a complete list of its members as known to date. Calvin had also previously described[64] an interesting fauna from a bed of black shales at Independence, Iowa, which *underlies* the main beds of the Devonian strata in that State, known as the Devonian limestones. The Rockford shales, containing the Lime Creek fauna, *overlie* these Devonian limestones, and several of the species occurring in the higher horizon are also found in these lower Independence shales. For the purpose of bringing out clearly the correspondence between the High Point fauna of Ontario County, and the fauna of the Lime Creek and Independence beds as given by Calvin, leaving aside the Cœlenterate fauna of the Lime Creek beds, the following table will suffice:

---

[56] Kayser, Zeitschr, d. d. Geol. Gesell, Band XXII, p. 841.

[57] Bull. Soc. Geol. de France, 2me ser., T. XVII.

[58] Bull. Soc. Geol. de France, 2me ser., T. XVIII, p. 18.

[59] Mon. British Dev. Brach., Pl. XIII.

[60] Geology of Iowa, Vol. I, Pt. II, 1858.

[61] Geology of Iowa, Vol. I, p. 187, 1870.

[62] Twenty-third Ann. Rep. N. Y. State Cab. Nat. Hist., 1873.

[63] Am. Jour. Sci., Vol. XXV, June, 1883.

[64] Bull. U. S. Geol. Survey, Vol. IV, No. 3, 1878.

Species.	Independence shales.	Devonian limestones.	Lime Creek beds.	High Point beds.
Naticopsis gigantea H. and Whitfield			*	
Paracyclas Sabini White			*	
Cryptonella Calvini H. and Whitf			*	
Terebratula navicella H			*	
Gypidula occidentalis H			*	
Gyp. munda Calvin	*			
Leiorhynchus Iris H			*	
Stenoschisma contractum, var. *saxatile* H			*	*
Rynchonella ambigua Calvin	*			
R. pugnus Martin				*
Atrypa reticularis Linnæus	*	*	*	*
Atrypa hystrix H	*		*	*
Atrypa aspera H				*
Cyrtina Hamiltoniæ, var. *recta*			*	
Spirifera MacBridei Calvin			*	
S. fimbriata Conrad			*	
S. cyrtinaeformis H. and Whitf			*	
S. Whitneyi H			*	
S. subumbona H	*			
S. Orestes H. and Whitf			*	*
S. Hungerfordi H			*	*
S. disjuncta Sowerby				*
S. mesacostalis H				*
S. bimesialis H		*		*
S. subattenuata H		*		*
Ambocoelia umbonata Con				*
Productella truncata H			*	
P. dissimilis H	*		*	*
P. speciosa H				*
Chonetes setigera H				*
Orthis impressa, var. *Iowensis* H			*	*
O. infera Calvin	*			*
Streptorhynchus Chemungensis Con			*	*
Strophonella hybrida H. and Whitf			*	
S. reversa H	*		*	*
Strophodonta exilis Calvin	*		*	*
S. variabilis Calvin	*		*	*
S. Canace H. and Whitf	*		*	*
S. arcuata H	*		*	*
S. Cayuta H				*
Crania famelica H. and Whitf			*	
Fistulipora occidens H. and W			*	*
Dadoxylon Clarkei Dawson				*

This fauna in Ontario County consists of twenty-six described species, indisputably of the age of the Chemung Period, as it contains eleven species previously recognized from the Chemung group of New York, and lies 600 feet above the last stratum known to contain fossils of the Naples shales. But it embraces a large intermixture of species that are totally unlike those of the Chemung of New York, and which find their counterpart only at a distance of nearly 1,000 miles to the west. Fourteen species are common to the High Point strata and the Lime

Creek beds overlying the Devonian limestones. Of twelve species occurring in the Independence shales, which underlie these Devonian limestones, nine occur also on High Point. Two species of the intervening Devonian limestones, viz., *Spirifer bimesialis* H., and *S. subattenuata* H., occur likewise at High Point. With the occurrence of these Chemung fossils abundantly at the base at the top of the Devonian series in Iowa, it becomes difficult to assign any definite horizon to the members of that series which will give them a correspondence with series in New York. The character of the fauna of the Independence shales leads us to the belief that the first Devonian fauna to appear in Iowa included an important representation from the Chemung fauna of New York in its probable migration westward from New York, to be succeeded in the limestones and shales above by a mingling of the Middle and Lower Devonian faunas of the east, and again by a return of the Chemung fauna with a more perfect development at the time of the deposition of the Lime Creek beds. That is, in the matter of relative age, all of these Iowa Devonian beds must be later in time of deposition than the Devonian of New York lying below the horizon of the High Point strata, and the age which saw the deposition of the Chemung sediments in New York was probably well toward its close at the time of the inception of the conditions in Iowa necessary for the deposition of the Independence shales.

List of the new species described in this paper.

Species.	Genesee shales.	Naples shales.
PISCES.		
1. Dinicthys Newberryi	*	
2. Pristacanthus vetustus		*
3. Palæoniscus Devonicus		*
4. Acanthodes pristis		*
CRUSTACEA.		
5. Ceratiocaris simplex		*
6. C. Beecheri		*
7. Echinocaris Whitfieldi		*
8. Beyrichia Dagon	*	
CEPHALOPODA.		
9. Goniatites Lutheri		*
10. G. Astarte	*	
11. Goniatites nodifer		
12. Orthoceras aciculoides		*
13. O. Ontario		*
14. O. filosum		*
15. O. Stebos	*	
16. O. Mephisto	*	
17. O. Asmodeus	*	
PTEROPODA.		
18. Hyolithes Neapolis		*
GASTEROPODA.		
19. Bellerophon incisus		*
20. Loxonema Noe		*
21. Platyostoma minutissimum		*
22. Pl. Belial	*	
23. Palæotrochus præcursor		*
24. Macrocheilus (?) Moloch	*	
PELECYPODA.		
25. Modiomorpha Chemos	*	
BRACHIOPODA.		
26. Spirifera Belphegor	*	
27. Sp. Pluto	*	
28. Leiorhynchus Hecate	*	
29. Lingula triquetra		*
CŒLENTERATA.		
30. Aulopora annectens		*

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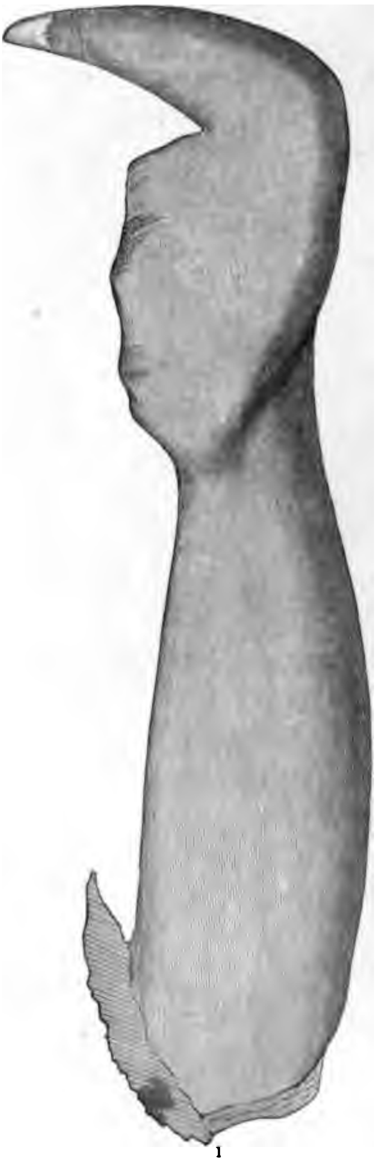
EXPLANATION OF PLATE I.

FIG. 1. *Diniothys Newberryi* Clarke. Right lower mandible. × ¼.
FIGS. 2, 3. *Palæoniscus Devonicus* Clarke. Scales. Fig. 2, × 2; Fig. 3, × 10.
FIGS. 4, 5, 6. The same. Cranial plates. × 2.
FIG. 7. *Pristacanthus vetustus* Clarke. Spine. *Ad nat.*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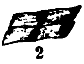
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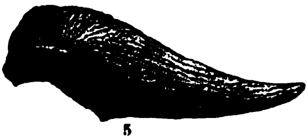
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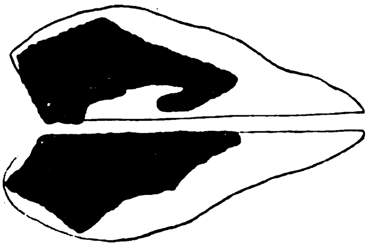
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DEVONIAN FOSSILS.

EXPLANATION OF PLATE II.

FIG. 1. ***Ceratiocaris Beecheri*** **Clarke. Showing three abdominal segments and the telson spines.** ***Ad nat.***

FIG. 2. ***Ceratiocaris simplex*** **Clarke. Carapace.** ***Ad nat.***

FIG. 3. ***Echinocaris Whitfieldi*** **Clarke. Carapace.** ***Ad nat.***

FIG. 4. **The same. Caudal plate with two telson spines.** ***Ad nat.***

FIG. 5. ***Beyrichia Dagon*** **Clarke. Side view. × 20.**

FIG. 6. **The same. Dorsal view. × 20.**

FIG. 7. **The same. Ventral view. × 20.**

FIG. 8. ***Goniatites Lutheri*** **Clarke.** ***Ad nat.***

FIG. 9. ***Goniatites Astarte*** **Clarke. Side view. × 12.**

FIG. 10. **The same. Front view. × 12.**

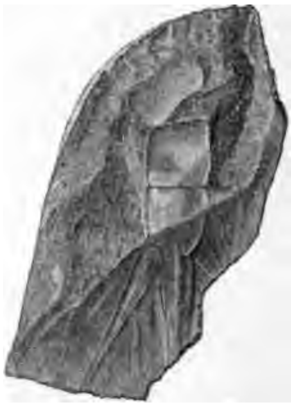
FIG. 11. ***Orthoceras aciculoides*** **Clarke. × 2.**

FIG. 12. ***Orthoceras filosum*** **Clarke.** ***Ad nat.***

FIG. 13. **The same. Opposite side of the same individual.**

FIG. 14. **The same. A younger example.** ***Ad nat.***

FIG. 15. ***Orthoceras Stebos*** **Clarke. × 12.**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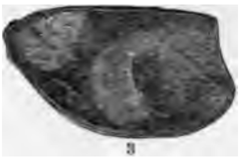
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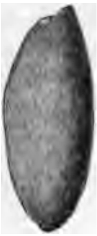
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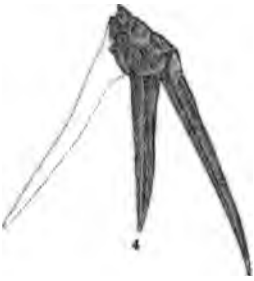
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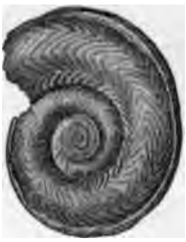
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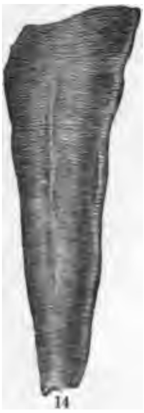
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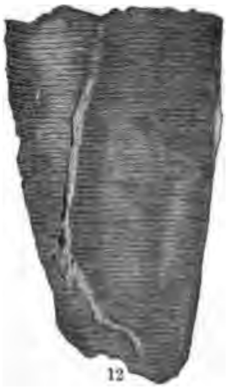
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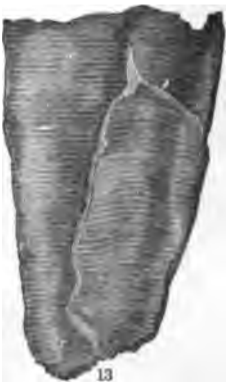
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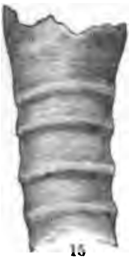
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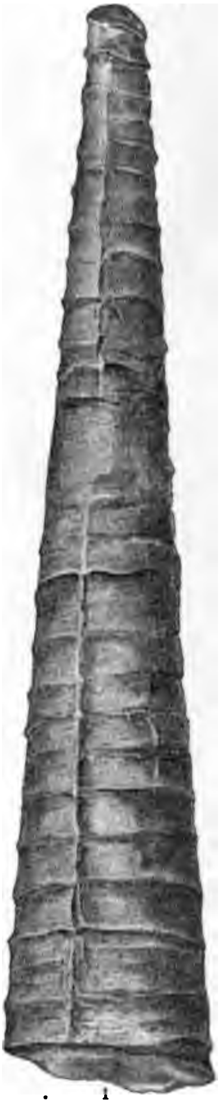
DEVONIAN FOSSILS.

EXPLANATION OF PLATE III.

Fig. 1. *Orthoceras Ontario* Clarke. *Ad nat.*
Fig. 2. *Orthoceras Mephisto* Clarke. × 12.
Fig. 3. *Orthoceras Asmodeus* Clarke. × 30.
Fig. 4. *Hyolithes Neapolis* Clarke. Dorsal surface. *Ad nat.*
Fig. 5. The same. Ventral surface. *Ad nat.*
Fig. 6. *Palæotrochus præcursor* Clarke. *Ad nat.*
Fig. 7. The same. × 2.
Fig. 8. The same. Showing the stoma. × 2.
Fig. 9. The same. View from above. × 2.
Fig. 10. *Loxonema Noe* Clarke. × 3.
Fig. 11. *Lingula triquetra* Clarke. *Ad nat.*
Fig. 12. *Spirifera Pluto* Clarke. × 10.
Fig. 13. *Spirifera Belphegor* Clarke. × 4.
Fig. 14. *Leiorhynchus* (?) *Hecate* Clarke. × 10.
Fig. 15. *Aulopora annectens* Clarke. *Ad nat.*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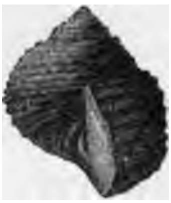
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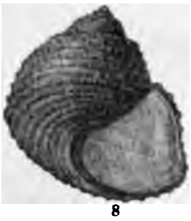
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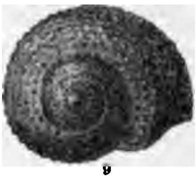
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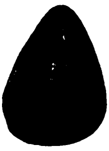
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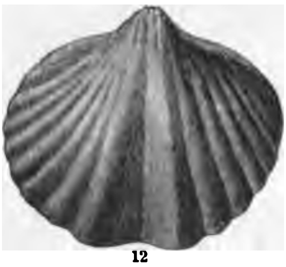
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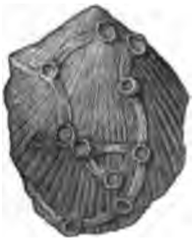
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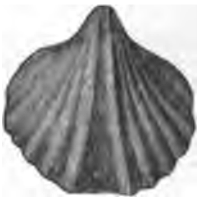
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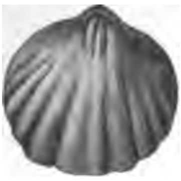
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DEVONIAN FOSSILS.

DEPARTMENT OF THE INTERIOR

BULLETIN

OF THE

UNITED STATES

GEOLOGICAL SURVEY

No. 17

WASHINGTON
GOVERNMENT PRINTING OFFICE
1885

UNITED STATES GEOLOGICAL SURVEY
J. W. POWELL DIRECTOR

ON THE

DEVELOPMENT OF CRYSTALLIZATIO

IN THE

IGNEOUS ROCKS OF WASHOE NEVADA

WITH

NOTES ON THE GEOLOGY OF THE DISTRICT

BY

ARNOLD HAGUE AND JOSEPH P. IDDINGS

WASHINGTON
GOVERNMENT PRINTING OFFICE
1885

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LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
Washington, D. C., February 16, 1885.

SIR: I have the honor to present herewith a paper by Mr. Joseph P. Iddings and myself, on the development of crystallization in igneous rocks, the result of an investigation of the extensive and well-selected lithological material collected by Mr. George F. Becker during his examination of the Comstock lode.

Many field geologists have maintained that the acidic lavas and pumices occurring on or near the surface would be found changed to granite, if it were possible to trace them downward to great depth. This has been denied, especially of late years, by other equally eminent authorities, who have claimed that geological periods were characterized by crystalline rocks, differing in composition and structural features.

Although much has been written upon the relation between surface flows and deep-seated igneous rocks, the problems have never been solved. Indeed they could not be solved before the application of the searching methods of microscopical research now employed in the study of crystalline rocks. Few localities afford the necessary conditions, and none surpass the Washoe district in furnishing the requisites for a proper investigation of such questions.

So far as I know, the results of no similar investigation showing the gradual transition in crystallization under pressure in continuous rock-masses have ever been published.

As the results of the work lead us to definite conclusions upon some important questions and bear directly upon the geology of the Comstock lode, it seems desirable that they should be published by themselves in a special bulletin as early as possible.

Very respectfully, your obedient servant,

ARNOLD HAGUE,
Geologist.

Hon. J. W. POWELL,
Director United States Geological Survey,
Washington, D. C.

ON THE DEVELOPMENT OF CRYSTALLIZATION IN THE IGNEOUS ROCKS OF WASHOE.

By Arnold Hague and Joseph P. Iddings.

INTRODUCTORY.

The Great Basin of Utah and Nevada, which has been the center of such widespread volcanic activity, presents the greatest possible variety of phenomena connected with the geology of igneous rocks. Within this well-defined area outbursts of lavas occur, forming high, rugged peaks, low, monotonous ridges interspersed with broad tables, extending for such long distances and covering such wide tracts of country as fairly to deserve the title of plateaus. Again, extravasated lavas may be seen as small isolated craters, as massive eruptions breaking out through lines of fissure and faults, and stretching out for miles along the base of the longitudinal ranges, or they may occur in small irregular hills, and occasionally in narrow dikes scattered over the country without any apparent law as to their distribution. Probably most geologists who have studied the region would agree that the country has nowhere been subjected to any extensive erosion since the outbursts of the greater part of these lavas. In consequence nearly all the later extrusions exhibit on the surface much the same features as they presented at the time they were forced upward through the underlying sedimentary strata or older crystalline rocks. While the region is one characterized by lavas of both acidic and basic types, presenting various glassy forms, there occur innumerable rocks showing every variety of microstructure, from nearly pure glass to others not only wholly crystalline but with a decided granitoid structure in the groundmass. The dikes which penetrate the older rocks are found in most cases to show a more crystalline structure than the massive eruptions or surface flows. This is especially the case with basic rocks; and although their connection with larger masses can seldom be traced, the conclusion seems inevitable that they must form portions of the same original magma, crystallized under different conditions. Although there has been collected throughout the area of the Great Basin a large amount of material which pointed in one direction and suggested a common origin and close geological connection between these extreme forms of rock structure, the subject has not been before closely studied, and direct proof of such an identity has been wanting. This is in part owing to the fact that erosion has failed to cut deeply into any great flow showing variations of structure, and in part to the want of sufficient data and material from any one locality upon which a searching mineralogical and microscopical examination could be undertaken, which would afford the necessary proof to warrant the assertion that difference in structure was mainly the result of consolidation under varying degrees of heat and pressure, or an expression of the rate of cooling.

In studying the collections of lavas from the Pacific coast volcanoes[1] we were forcibly impressed with the insensible gradations in the micro-structure in the groundmass of rocks of the same mineral composition from a purely glassy form to one wholly crystalline, and corresponding exactly in structure to a fine-grained granite-porphyry. The chain of microscopical evidence seemed so complete that we were convinced that the glassy and crystalline rocks were simply the extreme forms of the same magma, and that a highly crystalline rock brought in for diabase from one of the ravines of Mount Rainier could be nothing less than a crystalline variety of the hypersthene-andesite, which, judging from the collections, makes up the greater part of the volcano.

In seeking a locality in the Great Basin which could afford the necessary conditions for carrying out such an investigation as we desired to make, showing the actual transition from the glassy to the granitic structure, it was readily seen that the Washoe district was the only place offering sufficient material for the work. Indeed, there are few localities in the world presenting conditions which would permit of such an inquiry, and so far as we know the investigation has nowhere been previously undertaken, at least upon material adequate for a satisfactory solution of the problem. For the means of making this investigation we are greatly indebted to Mr. George F. Becker, who placed at our disposal the large lithological collections which he and his assistants had gathered in the course of their field-work preparatory to his report on the geology of the district. Owing to the unprecedented activity in mining which has characterized the district during the twenty-five years of its existence, we are enabled to examine the interior of the mountain by actual sections in a way unsurpassed in any other place. In addition to the magnificent horizontal section, over 4 miles in length, shown by the Sutro tunnel, and numerous vertical sections cut by shafts from 2,000 to 3,000 feet in depth, it is estimated from the official maps and records of the mining surveyors that over 180 miles of galleries and other openings have been run, and although a large part of these galleries pass through quartz and ore-bearing material of the vein many miles of levels in exploring new ground penetrate in every direction the east and west country, laying bare the internal structure of the mountain.

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[1] American Journal of Science, Vol. XXVI, September, 1883.

If the Virginia range were split asunder across the center of Mount Davidson it would not be possible to gain a more accurate knowledge of the region than is presented by this net-work of underground explorations. In the former case we should get a section of the mountain down to the level of the surrounding plain, but now we have, by means of the many deep shafts, a knowledge of the lower rocks many hundred feet below the level of the Carson Desert. And instead of a section cut on a vertical plane we have a mountain honeycombed in every direction by the untiring miner in search after bonanzas. Thus no natural section could surpass it for purposes of studying internal rock structure at great depths.

A mining region which has proved of such vast economic importance as the Comstock lode has necessarily excited intense geological interest, and owing to the great liberality of the National Government, scientific investigation of the district has gone on, with brief intervals of a few years, almost simultaneously with the exploitation of the precious metals. The amount of geological literature on the district which has been published is by no means inconsiderable, and a very large share of the space in the reports has been devoted to a consideration of the igneous rocks.

A brief summary of the results obtained by the more important investigators, including those of Baron von Richthofen,[2] Mr. Clarence King,[3] Prof. Ferdinand Zirkel,[4] and Dr. John A. Church,[5] is given by Mr. Becker in his elaborate work on the Geology of the Comstock Lode, recently issued. Since the publication of von Richthofen's report, nearly twenty years ago, followed quickly by his monograph on The Natural System of Volcanic Rocks, the knowledge of crystalline rocks has advanced with rapid strides, and the science of microscopical petrography has been almost wholly developed. In this advancement the study of the Tertiary volcanic rocks of the Washoe district has played a conspicuous part. In selecting, then, this district for the special purpose of this work, we have been guided by the knowledge that the principal geological features of the region are within the reach of all students of petrography. The results of our investigation, undertaken merely as incidental to a study of the volcanic rocks of the Great Basin, have proved so much more satisfactory and convincing than we were at first led to hope that we have no hesitancy in publishing them at this time. Moreover, the geological conclusions reached from the study of the lithological material are in many ways so diametrically opposed to those of our predecessors that we offer no apology for adding another brief paper to the many already published on the geology of the Washoe district.

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[2] The Comstock Lode, etc. Ferdinand von Richthofen. San Francisco, 1868.

[3] United States Geological Exploration of the Fortieth Parallel, Vol. III. "Mining Industry." Clarence King. Washington, 1870.

[4] *Id.*, Vol. VI, "Microscopical Petrography." Ferdinand Zirkel. Washington, 1876.

[5] The Comstock Lode, etc. John A. Church. New York, 1879.

Mr. Becker, in agreement with his predecessors, divided the igneous rocks of Washoe into Tertiary and Pre-Tertiary species, differing with them widely, however, as to where the lines should be drawn, and adding one or two more varieties of Pre-Tertiary rocks to those already recognized. His work possesses the very great advantage over the labors of those who preceded him, in that not only the Suttro tunnel, but all the deeper shafts and galleries were accessible to him, a large amount of ground having been opened since the earlier geological investigations were made. This recent material is of great value. The rocks obtained from these lower workings, when subjected to microscopical examination, so closely resemble in structure the so-called Pre-Tertiary types, that Mr. Becker extended the domain of the "older" rocks over a considerable area at great depths below the surface. This same material from the deep-seated localities affords, it seems to us, abundant evidence that the so-called Pre-Tertiary and the Tertiary rocks pass by insensible gradations into one another, and that evidence of a difference in geological age is wholly wanting.

Mr. Becker classified the rocks under the following heads: Granular diorite, porphyritic diorite, micaceous diorite-porphyry, quartz-porphyry, earlier diabase, later diabase, earlier hornblende-andesite, augite-andesite, later hornblende-andesite, basalt.

Representing these rocks from all parts of the Washoe district, we have had placed at our disposal more than two thousand hand specimens, six hundred from the surface, and over fourteen hundred from underground. From this collection there are now more than five hundred thin sections, including a number recently prepared to fill up certain gaps in the chain of our argument. Of these specimens those from underground, with the exception of the Sutro tunnel rocks, were collected mainly within the immediate neighborhood of the Comstock lode, while the surface specimens are confined to an area about 5 by 7 miles in extent.

Let us begin our analytical work by submitting the rocks to a searching microscopical and macroscopical scrutiny, to show what points of agreement exist between the so-called Pre-Tertiary and Tertiary eruptions, comparing rocks of the same mineral composition with each other.

DIABASE AND AUGITE-ANDESITE.

In considering the relation between these closely related rocks we will first make a comparative study of the thin sections prepared from both series. In the collection there are about one hundred and forty thin sections determined as unquestionably diabase or augite-andesite, and of these about twenty from each have undergone too much decomposition to allow of a satisfactory study of their feldspars, although they evidently agree in general characters with the fresher sections of the same class of rocks. Of the remaining one hundred thin sections forty were classed as diabase and sixty as augite-andesite.

Upon examining them somewhat hastily under the microscope two points are brought out in the most impressive manner. The first is the absolute identity in the nature and occurrence of the mineral constituents of the two rocks, and the impossibility of distinguishing many of those classed under one head from those classed under the other; the second is the gradual transition from a microlitic glassy groundmass to one holocrystalline, and from a microcrystalline groundmass of the minutest grain to one in which even the smallest grains are recognizable in thin section with the aid of an ordinary pocket lens. In studying them they may be arranged under eleven heads, according to the size and development of the grains of their groundmass, placing those with glass base at one end and those of the coarsest grain at the other. The different grades of crystallization may be stated approximately as follows:

1. *Groundmass* consisting of colorless glass, through which are scattered relatively few microlites of feldspar and pyroxene, and magnetite grains with contorted trichites. *Porphyritic crystals*, abundant plagioclase varying from 3^{mm}. long to very small size, averaging 1 or 2^{mm} long; pyroxene crystals less numerous. Example, thin section 50.

2. *Groundmass* of colorless or light-brown glass crowded with microlites of feldspar and pyroxene, and magnetite grains, showing a typical "felt-like" structure. *Porphyritic crystals* the same as in grade 1. Examples, thin sections 239, 426.

3. *Groundmass*, holocrystalline, composed of feldspar microlites, and indistinct grains about .005^{mm} in diameter, with grains of pyroxene and magnetite. *Porphyritic crystals* as in grade 1. Example, thin section 422.

4. *Groundmass*, holocrystalline, composed of feldspar microlites and grains of pyroxene and magnetite, the cementing material being crystallized in irregular patches with uniform orientation for the space of about .03^{mm}. *Porphyritic crystals* as in grade 1. Examples, thin sections 121, 122.

5. *Groundmass*, holocrystalline, the same structure as in grade 4; but the indistinct patches about .05^{mm} in diameter, though not of uniform size throughout the thin section. The feldspar microlites measure about .02^{mm} long. It is sometimes composed of grains from .01 to .02^{mm} in length with feldspar microlites. *Porphyritic crystals* as in grade 1. Examples, thin sections 35, 420.

6. *Groundmass*, holocrystalline, the same structure as in grade 5; the patches averaging as high as .1^{mm}, full of feldspar grains .01^{mm} in diameter and feldspar microlites .05^{mm} long by .01^{mm} wide. *Porphyritic*

crystals, abundant plagioclase varying in different thin sections from an average of 1.5^{mm} to 2.5^{mm}; pyroxene as in the preceding. Examples, thin sections 125, 389.

7. *Groundmass*, holocrystalline, composed of feldspar microlites about 0.1^{mm} long with granitoid grains of feldspar and quartz from .01^{mm} to .04^{mm} in size, together with grains of pyroxene and magnetite. *Porphyritic crystals*, plagioclase average about 2.5^{mm}, and begin to lose the sharpness of their outline. The same is true for the outline of the pyroxene sections. Examples, thin sections 169, 441.

8. *Groundmass*, holocrystalline, composed of granitoid grains of feldspar and quartz about .06^{mm} in diameter, and lath-shaped plagioclase, in variable proportions, besides pyroxene and magnetite. *Porphyritic crystals*, plagioclase 2.5^{mm} and smaller; the outlines of some rather indistinct; pyroxene as in grade 7. Examples, thin sections 53, 173.

9. *Groundmass*, holocrystalline, granitoid grains of about 0.1^{mm} and ill-defined lath-shaped plagioclase. *Porphyritic crystals*, plagioclase of 3^{mm} and smaller, some with very irregular border; pyroxene as in grades 7 and 8. Example, thin section 215.

10. *Groundmass*, holocrystalline, granitoid grains, about 0.1^{mm} in size, with porphyritic crystals nearly equaling the groundmass in amount. *Porphyritic crystals*, plagioclase 3.5^{mm} and smaller; pyroxene showing little change. Example, thin section 55.

11. *Groundmass*, holocrystalline, composed of plagioclase feldspar of 1.5^{mm} and smaller, with fewer granitoid grains of about 0.1^{mm}. In places it shows fine pegmatoid structure, formed of quartz and plagioclase, surrounding plagioclase crystals. *Porphyritic crystals*, plagioclase 3^{mm} long; the sharply-defined zonal structure of the main mass of the crystal surrounded by a poorly-defined border of feldspar, which loses itself among the adjacent grains; pyroxene, sometimes in well-defined, frequently in irregular-formed, crystals. Example, thin section 213.[6]

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[6] Agreeing with Professor Rosenbusch in general as to the origin of granular and porphyritic Structures in eruptive rocks; "Ueber das Wesen der körnigen und porphyrischen Structur bei Massengesteinen" in Neues Jahrbuch, 1882, II Band. We would briefly define the structural terms used throughout this paper as follows:

Granular.—The structure presented by an aggregation of grains of nearly the same size, or an aggregation in which there is a range in the size of grain, but with such a gradual transition that no particular individual stands out from the others in strong contrast.

Granitoid.—A structure in which the grains have an irregular form, produced by the mutual interference of adjacent crystals during their growth. The structure common to normal granites.

Porphyritic.—The structure which is produced when more or less well-defined crystals are imbedded in a groundmass, which is either glassy or holocrystalline, composed of crystals or grains of much smaller size than the imbedded crystals.

Pegmatoid.—The structure produced by the intergrowth of two or more minerals, usually quartz and feldspar, in such a manner that when seen in thin section they

In other words, we see that the porphyritic crystals show but slight modification in the different grades, the sharp outlines of the feldspars and pyroxenes being lost as the grains in the groundmass become larger, the nature of the inclusions in the feldspars also varying, as noticed further on. The essential variation takes place in the groundmass, which starting with a glass bearing few microlites, grows richer in them, then crowded until a very small amount of glass remains as a cementing base. This may be crystallized in microscopically cryptocrystalline particles, whose mineral composition is not determinable. As the size of the grain increases the cementing material assumes the appearance of uniformly oriented patches which, with increasing grain, are found to be in part quartz. In the higher grades the microlites have larger dimensions, and the cementing grains a granitoid form with or without pegmatoid structure.

In the highest grade (macroscopically a fine-grained porphyritic rock) it is difficult to draw any line between porphyritic crystals and groundmass, the more or less well-defined feldspars ranging from 3^{mm} in length to the size of the average granitoid grains of feldspar and quartz.

It is interesting to notice the appearance of a small amount of quartz as the last crystallizing mineral in the coarser-grained varieties of this pyroxene rock. It corresponds to the free silica, which remains after calculating the theoretical mineral composition from the chemical analyses of this rock, the excess being from 3 to 6 per cent.

Though the difference in the degree of crystallization between any two divisions of the scale is so slight, yet it represents more than actually exists, for the forms pass by imperceptible gradations into one another. If now the thin sections of both rocks are arranged according to this classification in columns as shown in Table I, we get at a glance some very striking results.

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appear as groups of grains of more or less regular form, each group having one optical orientation throughout. It is similar to the structure in graphic granite.

Granophyre.—The variety of pegmatoid structure in which the intergrown minerals are arranged in radiating, plumose or feather-like forms.

Microcrystalline.—An aggregation of crystalline grains which can only be recognized as such by the aid of the microscope. This includes many rocks which would be macroscopically cryptocrystalline, aphanitic, or lithoidal.

Microcryptocrystalline.—An aggregate of crystalline particles so small that the highest magnifying power fails to resolve them into individual grains.

TABLE I.—*Grades of crystallization.*

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
Augite-andesite				499							
				377	465						
				322	447						
				318	440						
				243	323						
				187	321						
				186	315						
				184	296						
				147	180	378					
				140	178	181					
		428	453	122	177	175					
		426	422	74	143	125					
		239	316	62	44	124					
		45	138	39	42	69					
		43	137	33	36	38	158	173			
	50	37	41	32	35	31	441	72			
Diabase				115	308	16	15	1	14	55	27
				121	344	114	18	53	215		280
				338	346	341	54	349	348		
				374	365	357	77	433			
				410	405	389	169				
					420		312				
					276		336				
							339				
							340				
							350				
							386				

The numbers in this and the following tables refer to the thin sections in the Washoe collection.

It appears that the coarsest-grained rocks with a well-defined granular structure are found only in the so-called diabase, while the extreme forms of andesite, as seen in column 8, show a tendency to a development of the same structure. On the other hand, the glassy and cryptocrystalline varieties are confined exclusively to the andesites. Moreover, the rocks of medium grain include much the larger number of thin sections from both series, the greater part of the diabase showing a coarser structure than most of the andesites, with, however, only a difference of about .02^{mm} in the size of grain. Now, each of the five grades (4 to 8 inclusive) for one rock has its exact counterpart in the other in size and shape of grain and structure of groundmass. On comparing the thin sections it becomes apparent that not only is the groundmass in each rock absolutely the same, but the porphyritic crystals are identical, giving the same results to every possible test that can be applied. They consist of the same species of triclinic feldspar, pyroxene, and occasional hornblende. The feldspars in rocks of corresponding grade present the same outlines, striations, similar extinction angles, zonal structure, and the same amount and character of inclusions. So much stress has been laid upon the nature of the inclusions in the feldspars[7] that an exhaustive study was made of them, comparing thin sections from rocks of the same degree of crystallization without discovering any difference. In each thin section the individual feldspars exhibit great diversity in the nature and amount of their inclusions, some bearing scattered rectangular glass bodies, others abundant smaller ones with rounded outlines, others being rich in grains of pyroxene and magnetite, others, again, combining all three, or, what is by no means uncommon, being nearly free from all inclusions. Fluid inclusions which might be considered primary are scarce in the medium-grained rocks, but were not found more abundantly in the "diabase" than in the andesite. As might be supposed, glass inclusions in the feldspars are more numerous in the glassy and fine-grained rocks, but upon careful search they may be observed in every thin section of the "diabase," from the finest to the coarsest. No line of demarcation can be drawn between these rocks based upon the glass-inclusions in their feldspars. In general, however, it may be said that the number of glass-inclusions decreases with increase in the degree of crystallization. In other words, they are a function of crystallization. This includes all thin sections given in the table, those in which the feldspars are clouded by decomposition being unfit for such a study. The fresh pyroxene consists of the same hypersthene and augite in both rocks, the hypersthene equaling or exceeding the augite in amount, and being the first to yield to decomposition.

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[7] Geology of the Comstock Lode, page 50.

Owing to the number of thin sections from these rocks and their various degrees of alteration, it is easy to trace the decomposition of hypersthene through all its stages, the augite in the same section remaining intact.[8]

This investigation leads then to the conclusion that in the thin sections of both rocks of the same degree of crystallization not only is the composition and structure of the groundmass identical, but that the relative abundance, size, and character of the porphyritic crystals scattered through this groundmass are the same.

Arranging now the hand specimens from which the thin sections were prepared in rows with the diabase and augite-andesite of the same degree of crystallization opposite each other, their macroscopic characters are seen to be identical. They agree in color, texture, fracture, and porphyritic crystals. Variations in one rock arising from stage of decomposition and amount and size of porphyritic secretions find their exact counterpart in the other. The conclusion then is inevitable that the greater part of the diabase is identical microscopically and macroscopically with the greater part of the augite-andesite and presents the transition between the glassy forms at one extreme and the coarsely crystalline forms at the other, and further, that the presence of a large percentage of hypersthene removes these rocks from the type of augite-andesite, properly so called, and places them under the head of pyroxene-andesite.

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[8] Notes on the Volcanic Rocks of the Great Basin, American Journal of Science, June, 1884.

SUTRO TUNNEL SECTION.

Having carefully examined all the specimens in the collection classed as diabase and augite-andesite, and shown that they belong to identical rock masses, let us now take up and study step by step the transition which occurs in a continuous rock mass along a definite line. For this work the Sutro tunnel, constructed for the purpose of draining the Comstock lode, furnishes an exceptionally fine geological section through 20,400 feet, or nearly 4 miles, of igneous rocks lying east of the vein. The tunnel enters near the lower foot-hills in Carson Valley, and runs a little north of west, approximately at right angles to the course of the vein and trend of the range, and directly toward Mount Davidson, the highest and largest mass of the mountain group. Probably few lines could have been selected more advantageously situated for exhibiting the structure of the region. A collection of two hundred and seventy specimens, carefully selected at intervals of 100 feet and less, together with their numerous thin sections studied in connection with the surface rocks immediately above ground, shows clearly the different kinds of rock which the tunnel penetrates and their variations in structure.

Referring to Sheet VI of the Atlas[9] we observe that, starting from the mouth, the tunnel, according to Mr. Becker, passes through later hornblende-andesites with occasional masses of older augite-andesite, and at 10,000 feet enters the main body of the latter rock. Thin sections from about this point show it to be holocrystalline, of the grades 4, 5, and 6. The rocks for the next 2,000 feet are much decomposed, many of them full of pyrite. Between 11,400 and 11,700 feet occurs a dike of dense white rock, resembling a broad dike met with further in the tunnel. From 12,000 to 13,700 feet the andesites show more or less alteration, the porphyritic crystals being small, and the iron magnesia silicates indeterminable in the hand specimens. Of the five rocks in this part of the tunnel, of which we have thin sections, four carry hornblende associated with pyroxene, two showing a large amount of the former. At 13,700 feet a dike of quartz-bearing hornblende-pyroxene rock is met with possessing quite a different groundmass structure from that of the andesite through which it cuts. Between 13,800 and 13,900 feet another white dike occurs like that already mentioned, followed by a hornblende-pyroxene rock of coarse grain (grade 8). Here the tunnel cuts a dike 1,400 feet in width of a dense white rock carrying relatively few porphyritic crystals of feldspar and still less mica, but without hornblende or pyroxene, and having a groundmass-structure wholly unlike any found in the andesites. In the Sutro tunnel section this rock is indicated by lines of shading denoting solfataric action, but it is quite evident that it is younger than the andesite, as it is found penetrating it. The rock in every way corresponds in structure to the so-called felsitic quartz-porphyry from the surface near Roux's ranch and the Red Jacket mine.

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[9] Geology of the Comstock Lode. Atlas, Sheet VI.

Following this dike of white rock the next 1,000 feet of the tunnel cuts through augite-andesite, the nine thin sections of which range in grades of crystallization from four to seven, three showing hornblende. At 17,100 feet a characteristeric rock is met, rich in fresh, brown hornblende, and having the same microstructure as the andesites previously observed (grade 7), yet so much less altered than the surrounding rocks on both sides that it seems evident that it occurs here as a dike. According to the published map section, however, there begins here a continuous body 1,500 feet in width of hornblende-andesite, but the hand specimens studied macroscopically show it to correspond in every particular to the augite-andesite; and of the eleven thin sections from this body, with the exception of the fresh rock above noticed, only two show small amounts of hornblende, the remaining eight not carrying any that could be definitely determined. They range in crystallization from grades 5 to 8 eight, and have the same microscopical character as the augite-andesite to the east. It appears to be cut in three places by mica-hornblende rocks differing essentially from the surrounding andesite, and corresponding in microstructure and mineral composition to the so-called mica-diorite from the head of Ophir Ravine (thin section 459). Referring again to Sheet VI, it will be seen that the tunnel after passing through the body represented as hornblende-andesite enters the diabase. Again, hand specimens from several hundred feet upon each side of the supposed line of contact are indistinguishable from one another, and the thin sections show identical structure and the same degree of crystallization.

Examining now the twenty-seven thin sections from the diabase cut by the main tunnel and the north and south branches,[10] the first of which is 4,400 feet, and the second 4,000 feet in length, they are seen to vary in degree of crystallization (with one marked exception) from grades 5 to 10, averaging 8, or two grades higher than the average of augite-andesite. In the hanging wall west of the Savage mine connection the tunnel goes through diabase, and again also west of the vein, then passing through diorite it again cuts diabase 180 feet west of the Savage connection, and at the end encounters a mica-diorite like that observed further to the east. An examination of the thin sections recently made from the diorite showed in one case that the iron magnesia silicates, now completely altered to chlorite, were pyroxene and not hornblende, and in the other two cases, while their original nature is not determinable, the microstructure of the rocks is the same as that of the most crystalline diabase.

Let us reject for the present the thin sections which represent the dikes or later intrusions cutting through the main rock mass, and place the others in columns (Table II) according to the scale of crystallization, already adopted, arranging them in the order in which they occur in proceeding from the mouth to the head of the tunnel.

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[10] Geology of the Comstock Lode. Atlas, Sheets VIII and IX.

TABLE II.—*Grades of crystallization.*

		Distance from mouth of tunnel.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
Augite-andesite		41			138								
		49				140							
		54					141						
		403					144						
		1, 400					315						
		2, 500			316								
		5, 234				318							
		9, 761				32							
		9, 800					321						
		9, 971				33							
		10, 000				147							
		10, 055						81					
		12, 000						149					
		12, 300			151								
		12, 500				153							
		12, 600				154							
		13, 700						95					
		14, 090								72			
		15, 680						69					
		16. 066					71						
		16, 384				74							
		16, 700				322							
		16, 758					84						
		16, 800					323						
		(†) 16, 884							158				
		16, 921					324						
		16, 921					63						
		17, 000					325						
Hornblende-andesite		17, 100							326				
		17, 300								327			
		17, 500					328						
		17. 600						290					
		17, 700					329						
		18, 100					330						
		18, 300					331						
		18, 500								332			
		18, 600							333				
		18, 700								334			
		19, 000						335					
Diabase		19, 155								22			
		19, 200								53			
		19, 464							77				
		19, 540							79				
		19, 700							80				
		19, 805							15				
		19, 910							18				
		*19, 910									14		
		19, 971							169				
		20, 100							336				
Diorite		(†)									508		
		20, 120								506			
		20, 160									507		
Diabase	South branch.								337				
					338								
									339				
									54				
									340				
								341					
								342					
								343					
							344						
									345				
							346						
	North branch.							16					
									350				
											348		
										17			
								347					
												55	

* Hanging wall of Savage.

† Lode limit Savage.

The important points clearly brought out by the table are, first, that there is in general a gradual increase in the degree of crystallization of the rock from the outer foot-hills as the tunnel approaches the central core of Mount Davidson; second, that while the rocks classed as augite-andesite occur more at the lower end of the scale, and the diabase at the other, by far the greater part of both rocks overlap each other in the intermediate columns, and are indistinguishable from one another. The glassy forms of pyroxene-andesite, abundant enough on the surface, are unknown in the tunnel. It is worthy of note that as the north branch approaches Mount Davidson there is exhibited a tendency toward a coarser crystallization, while on the other hand the south branch, as it turns away from the central mass, indicates an equally strong tendency to a finer-grained structure

GRANULAR DIORITE

Reference has been made in the text and in Table II to the diorite at the head of the Sutro tunnel upon the west side of the Comstock lode, which we have placed with the pyroxene rocks. This rock, classed by Mr. Becker as granular diorite, forms the east front of Mount Davidson and presents the most conspicuous topographical feature in the district. Of the three specimens of granular diorite from Mount Davidson having thin sections only one (213) was originally determined as unquestionably diorite, the others being left doubtful. Thin sections recently prepared from three typical localities, namely, the summit of Mount Davidson (488), Ophir Ravine (489), and the Sutro tunnel (507 and 508), show that they are identical with those previously examined. Moreover, they agree in every particular of microstructure and mineral character with the coarsest-grained pyroxene rock found to the east of the vein from the north branch of the Sutro tunnel (55) and the C. and C. shaft (27).

The light-green, fibrous hornblende shows its uralitic nature by having the characteristic eight-sided outline of pyroxene in cross-section. Both the diabase from Ophir Ravine (216) and the diorite from the Savage mine (463) show the transition of the pyroxene into fibrous hornblende. While both rocks are at present hornblendic, it is evident that their hornblende is for the most part secondary, and that they are coarsely crystalline pyroxene rocks with the hypersthene and augite altered to uralite.[11]

The identity of the granular diorite with the coarse-grained diabase is well brought out on comparing thin sections 507, 508, 488, 489, 213, 214, 360, and 463 of the former with 14, 280, 215, 216, 27, and 55 of the latter; also on comparing hand specimens 109, 215, 303, 567, 568, and 1125 with 307, 264, and 364.

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[11] The diorite from Ophir Ravine (40th Parallel Collection, No. 22620, thin section 157) shows both uralitic hornblende and fibrous hornblende, which appears to have resulted from primary hornblende. Some of the plagioclase bears minute glass inclusions; the groundmass shows fine pegmatoid structure.

The difficulty of distinguishing between these rocks seems to have been realized by Mr. Becker, for he admits that the gray granular diroite may be mistaken for granular diabase;[12] and again, in speaking of the locality in Ophir Ravine,[13] says: "This bears a very strong outward resemblance to a granular diorite, and it seems impossible to make out a sharp contact between the two rocks. I am by no means sure that it should not be regarded as a local modification of diorite rather than an independent eruption."

PORPHYRITIC DIORITE AND EARLIER HORNBLENDE-ANDESITE.

If we arrange the surface specimens on a table as nearly as possible in accordance with their relative positions on the map, we are at once impressed with the similarity between those labeled diorite and many classed as andesites and with the difficulty of establishing any line of demarcation between the two rocks. Another remarkable fact is the gradual transition from the most crystalline forms of which Mount Davidson is chiefly made up, outward as from a center to less crystalline and glassy varieties.

It soon becomes evident, upon a cursory examination carried on in the same manner as in the study of the proxene rocks that the different varieties of porphyritic diorites have as to macroscopical habitus their exact counterparts among the earlier hornblende-andesites. The following surface specimens may be cited for the purpose of comparison:

Diorite.	*Hornblende-andesite.*
481	like 157.
478, 474	" 493.
125	" 439.
483	" 211, 78, 528, 531.
482	" 213.
306	" 116.
449, 312	" 486, 487.
185, 477, 41	" 225, 184, 158.
59, 479, 42, 40	" 217.
558	" 494, 532, 536.

Every variety is here represented; there may be found those with large porphyritic crystals, and those with very small ones, ranging from much decomposed to quite fresh forms. They agree in texture and color of groundmass, in character of fracture and mode of weathering, and in size and relative abundance of porphyritic crystals. In a word, by every macroscopical test that can be applied they are indistinguishable in the hand-specimens. Taking up now the sixty thin sections representing the surface collection of both these rocks and subjecting them to the same comparative microscopical scrutiny applied to the pyroxene rocks, they still fail to present any distinguishing features. The groundmass of the porphyritic diorites varies from cryptocrystalline to microcrystalline, formed sometimes wholly of lath-shaped microlites, others having a granular structure with microscopic feldspars scattered through it. Now, for every variety of groundmass among the porphyritic diorites from the surface there can be found among the andesites identical rocks of the same degree of crystallization, corresponding in structure, size of grain, and mineral composition. The same identity holds good for the porphyritic crystals; the feldspars show the same inclusions, and the hornblendes and pyroxenes present precisely similar characters in both rocks. Quite in accordance with the observations upon the pyroxene-andesites there are a few hornblende-andesite sections which show glass in the groundmass, and at the same time a corresponding increase in the amount of glass-inclusions in the feldspars, but by far the greater number of rocks represented are holocrystalline.

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[12] *Loc. cit.*, p. 39.

[13] *Loc. cit.*, p. 197.

MICA-DIORITE AND LATER HORNBLENDE-ANDESITE.

The rocks classed by Mr. Becker as later hornblende-andesite[14] we prefer to call hornblende-mica-andesite, for the reasons that they are characterized in distinction from the earlier hornblende-andesite by an abundance of mica as an essential ingredient, and are at the same time more acidic in composition; and while the name later hornblende-andesite answers well enough for the Washoe district, it is hardly applicable in other regions of the Great Basin where these rocks frequently occur, forming large extrusions without any association on the surface with earlier hornblende-andesite. The specimens in the collection vary greatly in the abundance and size of porphyritic crystals, in texture and color of groundmass, as well as in the relative proportions borne by the constituent minerals to one another. This variation in habitus is greater than in either hornblende or pyroxene andesite. The mineralogical features and diversity of habitus have been well described by Mr. Becker in his monograph.

The mica diorites are few in number and represent comparatively small masses scattered over the surface or exposed by the underground workings of the mines. Nevertheless when considered in connection with the other mica bearing diorites in the collection they form a much larger class, presenting an equally varied structure and composition, and for each variation, with the exception of the more crystalline forms, the exact counterpart may be found among the later hornblende-andesites. By placing the corresponding forms in parallel rows, as in the case of the diorites and earlier hornblende andesites, it is found quite impossible to distinguish them, the great variation in macroscopical appearance bringing out all the more forcibly the absolute identity of the two rocks.[15]

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[14] These rocks are the "trachytes" of Baron von Richthofen, Mr. Clarence King, and Prof. Zirkel. Mr. Becker has shown that according to the modern classification now generally adopted by lithologists they belong to the andesite group.

The thin sections clearly show the same correspondence in minute structure, although a thorough comparative study is not always possible, as the sections from the mica-bearing diorites are mainly from underground specimens exhibiting more or less decomposition, while those from the later horneblende-andesites are for the most part fresh. The only thin section (No. 101, 1,000 feet from the Silver Hill mine) of the fine grained mica-diorites in which the feldspars still remain unattacked exhibits glass inclusions in the fresh feldspars, and in the relatively coarse-grained varieties (grades 8, 9, 10) they may be seen in profusion, while they are almost wholly wanting in those of the coarsest grain (grades 12, 13, 14) which abound in liquid inclusions, as might be sup-

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[15] The following table represents the numbers of the hand specimens of the two rocks which correspond each to each:

Later hornblende-andesite.	Mica-bearing diorite.	
From Sutro tunnel collection.	*From surface collection.*	*From mining collection.*
7	505	
10, 11, 12	561	
29, 30		548, 821, 827, 755
31		867, 1459
32		804
33		764
34	563	
36	156	
43	556	
45, 112	554, 555	
75	557	
79	553	
84		578
90, 91		456
100		455
103	560	
105		802, 808 (*b*)
114		803, 1407
117		806, 807
118		458
From surface collection.		
26	11	
79		809 (*b*) 810 (*b*)
92	448, 475	388, 859, 1331
97		462
101	564	
103	159	
291	107, 550	1417, 1420
292	552	
293		805
302	562	405, 1247, 1271

posed. In this series of rocks also we see that the range from glass to liquid inclusions varies with the degree of crystallization, as already shown.

These last three grades of crystallization have the following characteristics, it being borne in mind that the iron magnesia silicates in the series in question differ from those of the series described on pages 13 and 14.

Grade 12.—More or less well-defined crystals of plagioclase, 3.5mm and smaller, with very irregular patches of mica and hornblende, in a groundmass of most irregularly shaped, interlocking grains of feldspar and quartz, which range from 1.8mm to 0.6mm in diameter. Example, thin section 291.

Grade 13.—The average size of the granitoid grains somewhat larger than in grade 12, and exceeding in many cases the size of the better outlined crystals. Example, thin section 460.

Grade 14.—A thoroughly granitoid structure to all the mineral constituents, which range in size from 3.5mm to others quite small, the greater part of them averaging as high as 1.5mm. Example, thin section 268.

Arranging the thin sections according to their degree of crystallization (Table III), the scale adopted being approximately the same as that given in the table for the pyroxene rocks, the relation of the later hornblende-andesites to the mica-bearing diorites will be seen at a glance:

TABLE III.—*Grades of crystallization.*

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.
Later hornblende-andesite.		483												
		478												
		477	475	471										
		476	470	467										
		474	320	390										
		472	319	75										
		48	317	66	375	397								
		47	59	65	230	70								
		46	51	64	49	67								
Mica-bearing diorite				86	10	252		265	247	300		291	460	85
				91	19	398				429				96
				446	94	402								268
				172	95	411								
					97	443								
					200	160								
					203									
					205									
					399									
					412									
					444									
					459									
					159									
					162									

The extreme glassy form represented in the table of pyroxene rocks does not happen to occur among the thin sections of later hornblende-andesite, but a large proportion of them represent a glassy groundmass crowded with microlites, while all of them belong at one end of the series. On the other hand all of the so-called mica-diorites possess a holocrystalline groundmass, range from finely microcrystalline to a macrogranular or granitoid structure, in which the smallest grains are visible to the naked eye. They reach a somewhat coarser grain than was recognized among the pyroxene rocks, the scale being extended from eleven, in Table I, to fourteen grades. As indicated in the table, the three highest grades of the andesite correspond to the three lowest of the diorite and are identical with them in microscopical detail. Moreover more than one-half the thin sections examined fall within these three grades. A separation of the two rocks from a petrographic standpoint seems to us quite impossible.[16]

QUARTZ-PORPHYRY, DACITE AND RHYOLITE.

Baron von Richthofen, in his study of the Washoe district, evidently paid but little attention to these rocks and dismissed them with brief mention, regarding them as of slight importance in questions bearing upon the geology of the vein. He considered them, however, as earlier than the Tertiary volcanic lavas. Mr. Clarence King, after careful examination of the field, referred them upon geological evidence to the Tertiary series, and Professor Zirkel, after a microscopical examination of the thin sections, determined them as belonging to both dacite and rhyolite. The results of Mr. Becker's investigation led him to the conclusion that the absolute uniformity of the rock masses precluded their separation into Tertiary and Pre-Tertiary eruptions, while geological observation and an examination under the microscope of certain specimens, following the same methods of reasoning as adopted for other rocks, induced him to agree with von Richthofen as to their age. From our own knowledge of the district[17] and close study of the specimens and thin sections we have arrived at the conclusion reached by Mr. King as to the age of this series of rocks, and agree with Professor Zirkel as to their specific determinations.

Omitting for the present the geological evidences bearing upon the age of the rocks plotted on the Washoe map as quartz-porphyry, let us first consider their microscopical and macroscopical habitus. They are for the most part rich in porphyritic crystals of quartz, feldspar, and mica, with some hornblende, but vary greatly in the relative proportions of these minerals. Those with few quartzes, but rich in feldspar, plagioclase being in excess of orthoclase, accompanied by much mica and less hornblende, correspond to dacite in mineral composition, and resemble the dacites from Mount Prometheus in the Toyabe Range. In others, characterized by abundant quartzes, plagioclase seems occasionally to predominate over orthoclase; but in most of them the latter feldspar is in excess, particularly in those poor in mica and hornblende. The region is one where not only both dacite and rhyolite occur, but one where the transition members are well represented.

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[16] Similar petrographic relations apparently exist among the rocks of the Banat described by J. Niedzwiedzki in an article entitled "Zur Kenntniss der Banater Eruptivgesteine." Tschermak's Mineralogische Mittheilungen. 1873. iv, 255–261.

[17] One of the writers of the present article was geological assistant to Mr. Clarence King when he made his study of the Comstock mines in the winter of 1867–'68 and is quite familiar with the occurrence of the igneous rocks of the Washoe district.

In macroscopical habitus they exhibit great variations, arising from the abundance or scarcity and size of the porphyritic crystals, and from the color and density of the groundmass. Many hand specimens are perfectly fresh and show the brilliant sanidins so characteristic of the dacites and rhyolites of the Great Basin, and a microscopical examination proves conclusively their identity. The groundmass of many of them often shows within the small area of a square millimeter the greatest diversity of structure, being partly spherulitic, axioltic, and microcrystalline, with glass either clear or clouded (microfelsitic), presenting elongated, curved patches and streaks, a structure described in great detail by Professor Zirkel in his monograph on microscopical petrography already mentioned. The porphyritic quartz contains in most cases only glass, less frequently liquid inclusions, the latter, however, occurring in greater numbers than is usually met with throughout the Great Basin. As these rocks are somewhat removed from the center of mining activity, there are no good underground exposures, and in the few places where they have happened to be cut in exploration they show so much decomposition or occur so fine-grained as to offer very little variation in degree of crystallization. It may be said, however, that there exist no petrographic distinctions between these rocks and many of those found in the ranges to the eastward. We consider them as partly dacite and partly rhyolite, and, judging from the specimens in the collection, without any sharp line of demarcation between them.

YOUNGER DIABASE, BLACK DIKE, AND BASALT.

The rock considered by Mr. Becker as younger diabase and of Pre-Tertiary age is nowhere recognized on the surface. It only occurs as a narrow dike in the immediate neighborhood of the Comstock lode, where it has been followed for more than a mile along the lower levels of the mines. In the upper levels it has undergone so much decomposition that little could be made out of it by the earlier investigators, and for years mining engineers have designated it simply as the "black dike."

According to Mr. Becker, who has given careful attention to the occurrence of this rock, it has not been traced north of the Savage mine, but thence south to the Overman, "it generally marks the contact between the older diabase and the west wall with precision."[18] It extends as far south as the Caledonia, presenting everywhere great uniformity, and never measuring more than 6 feet in width. The rock was represented by only three thin sections, showing but slight variations in structure, and composed of triclinic feldspar, augite, magnetite, and what Mr. Becker described as "clouds of a smoky brownish substance" which he did not determine. Now it is quite evident that much of this substance occupies spaces with the six sided and lozenge-shaped outlines characteristic of olivine; this is well shown in thin section 274. Two new sections from the Yellow Jacket (1278) and the Belcher mines (1322) show in the former a coarser grain and in the latter a much finer grain, having a large amount of fine-grained groundmass with small porphyritic feldspars, augites, and decomposed olivines, the typical structure of many Nevada basalts.

The five thin sections, arranged in the following order, 509, 466, 289, 274, 511, present a gradual transition from coarser to finer grain, the porphyritic crystals diminishing in size and number as the rock becomes more and more porphyritic and carries more groundmass. The augites and feldspars are fresh, while the olivines are wholly decomposed to a greenish-brown fibrous substance, which is also disseminated through the groundmass. It is to be noted that the augite in this rock is quite fresh, while in many of the andesites it exhibits much alteration.

Turning now to the surface rock which has been regarded by every field observer as basalt, we find that it occupies very limited areas, only occurring in a few isolated patches, closely associated with the dacite and rhyolite in the neighborhood of American Flat. Thin sections from these surface rocks show a ground mass without the chlorite, similar to that in the underground rock (thin section 511), but with fewer and smaller porphyritic feldspars. The augite is of the same character, and the fresh olivine presents the same form and size as the spaces occupied by the "smoky brownish substance" in the black dike. Comparing hand specimens of the two rocks, those from the black dike are seen, as might be expected, to be slightly denser than the surface basalt. In specimen 1202 from the dike the decomposed olivines are especially prominent, and give the rock exactly the same habit as the basalt specimen 398, from southwest of Roux's ranch, the latter differing from it only in being somewhat porous, of a steel-gray color instead of greenish-black, and in having fresh, glassy olivines. We fail to see any petrographic distinction between the two rocks.

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[18] *Loc. cit.*, p. 199.

GEOLOGICAL AND CHEMICAL EVIDENCE.

In the discussion of the igneous rocks of the Washoe district we have confined ourselves mainly to a comparative lithological study of the rocks of the same mineral composition which have been classed by Mr. Becker as Tertiary and Pre-Tertiary eruptions, and have endeavored to show that they were identical masses presenting insensible gradations from the glassy to the granular structure. We have omitted for the most part the geological and chemical evidences, which not only strengthen the position we have taken, but clearly explain many difficult problems in the structural geology of the region and the relations of many of the rock masses to each other. It is a fact of some interest that nearly all geologists who have examined the district have been impressed with the apparent great variety in the igneous rocks represented. They have all easily recognized the more characteristic types, such as the granular rock which forms the bold front of Mount Davidson, the porphyritic rocks upon the flanks of the mountain variously designated as porphyritic diorite, propylite, and hornblende-andesite, and the glassy and fine-grained rocks mainly referable to pyroxene-andesite. But the moment they tried to outline their areas they were immediately beset with what seemed insurmountable difficulties. This is in part owing to the great amount of decomposition occurring in the neighborhood of the Comstock lode, but in greater part to the gradual transition in crystalline structure. Extreme forms were readily determined, but where to draw the line between them seemed impossible to decide.

The supposed differences between the porphyritic diorite and hornblende-andesite, which we can but regard as one rock, were so obscure as to make their determination one of great difficulty and led to a most confusing entanglement.[19] That this confusion arose from superficial appearances produced by decomposition seems evident, the more decomposed forms being classified for the most part as the older rock. In his discussion of the hornblende-andesite, Mr. Becker says,[20] that through the decomposition of this rock "every variation in coarseness of grain also becomes apparent," and "all these changes tend to diminish the sharp definition of the porphyritic crystals and give the mass the look rather of an older dioritic porphyry than of a volcanic rock." Now, in speaking of the porphyritic diorite he says,[21] "From some peculiarity either in composition or texture the porphyritic hornblende-diorites have undergone extensive decomposition" and only "two or three small masses" were found in a fresh state. From a study of these rocks it seems evident that the apparent coarseness of grain of most of the so-called porphyritic diorites is derived solely from the decomposition of hornblende-andesite.[22] It is a most noteworthy fact that the decomposed forms of andesite occur in areas of fresh rock, while the somewhat fresh diorites are found in areas of general decomposition. The propylite of Baron von Richthofen and Mr. Clarence King for the most part belongs to this decomposed rock, the latter geologist remarking[23] "nearly all the propylite observed by us is decomposed." The distinguishing features of propylite were considered to be its high degree of crystallization and a certain characteristic habitus of the hornblende, the former closely relating it in structure to the hornblende-porphyrites, while the latter character tended to separate it superficially from the andesites with which it is unquestionably connected geologically. On the one hand we quite agree with Mr. Becker, who has ably shown after a rigid examination that a greater part of the propylite cannot be separated from the hornblende-andesite, and that there exists no evidence of its pre-andesitic eruption. He has clearly shown that the propylite of Washoe has no claim to be considered as an independent rock species, its change in habitus depending wholly upon decomposition. On the other hand our own work, showing the transition from glassy lavas to somewhat highly crystalline forms, compels us to agree with the earlier investigators, and to relegate his Pre-Tertiary porphyritic-diorite to the Tertiary hornblende-andesite. A comparison of the geological maps accompanying the works of Mr. King and Mr. Becker shows how embarrassing the difficulties were in drawing correct lines of demarcation between the supposed Pre-Tertiary and Tertiary masses. Over a very considerable part of the area they fail to agree. In general the latter geologist regards the south flanks of Mount Davidson as covered by hornblende-andesite, and the north flanks by diorite, the former geologist considering both north and south flanks as covered by propylite and of Tertiary age.[24]

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[19] Geology of the Comstock lode, pp. 42, 87, 89.

[20] *Loc. cit.*, p. 58.

[21] *Loc. cit.*, p. 39.

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[22] The collection contains several series of specimens showing the various stages of decomposition of the rocks, classed as hornblende-andesite and porphyritic diorites. Among the former are numbers 486, 487, and 569 to 574. Among the latter, 448, 449, 451, 497, 498, 450, and 310, 311, 312.

[23] U. S. Geological Expl. of 40th Parallel, Vol. I, p. 557.

[24] In this connection it may be profitable to review the literature upon the propylite of Schemnitz in Hungary, a region which presents in many respects a close resemblance in its geological history to Washoe. Dr. Doelter (Verhandlungen der k. k. geologischen Reichsanstalt, 1879, p. 27), after a mineralogical and chemical study of the altered rocks recognizes the microscopical distinctions pointed out by Zirkel, especially in the quartzose rocks, but finds isolated masses which unite many of the characters of both andesite and propylite. He fails to find any difference in mode of occurrence or geological age between the two rocks. Vom Rath, probably after a study of the more crystalline portions, concludes that the propylite properly belongs to diabase and presents structural features quite unlike a Tertiary andesite. With his intimate knowledge of the Schemnitz region Professor Szabó, in the same number of the geologischen Reichsanstalt, from a geological standpoint denies the independent [illegible]ption of propylite. Dr. A. Koch, in a paper entitled "Neue petrographische Un[illegible]chung der trachytischen Gesteine der Gegend von Rodna" (Verhandlungen der

The structure of the main body of the mountain is well brought out by the Sutro tunnel. It is shown to be for the most part a body of pyroxene-andesite extending from the central core of Mount Davidson, where it is well exposed, eastward to the outer foot-hills, where it is largely concealed by hornblende-mica-andesite, which breaks through it and covers the surface, the relations between the two rocks being well exhibited by the tunnel section. As already shown, there is a gradual and steady increase in degree of crystallization as we pass toward the central core, the pyroxene-andesite which forms the west country rock being one or two degrees coarser than the east country rock. In general the body west of the lode opposite the central portion of Mount Davidson is somewhat coarser than the rock to the eastward, but this does not hold true either to the north or the south. This is explained by the fact recognized by all geologists that the vein is situated along a line of great faulting, the displacement being quite sufficient to bring different portions of the same rock mass into juxtaposition. Along the line of the vein solfataric action has produced so much decomposition, especially to the eastward, that comparative petrographic studies of the walls is a matter of considerable difficulty. Nevertheless, the distance is so great and the exposures in the many tunnels so numerous that the evidence of identity of both walls seems conclusive. Let us consider, for example, a cross-section in one mine. On the 1,450-foot level of the Sierra Nevada mine a small body of pyroxene rock has been identified to the west of the main shaft, but to the east of the shaft the country rock is so decomposed that sufficiently fresh material for accurate identification was not obtained for 1,600 feet. At this point, where unaltered material occurs, it is shown to be a pyroxene rock. Now, although the rock has undergone so much alteration as partially to preclude specific identification, there is no evidence at hand that through-

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k. k. geolog. Reichsanstalt, 1880, Literaturnotizen), is of the opinion that a separation of Grünstein-trachyte (propylite) from andesite is inadmissible, since he shows that both rocks are connected through transition forms. He points out that the principal difference between them is in the structure of the groundmass, the propylite being holocrystalline while the true andesite of Hungary always contains more or less glass. He maintains that the question whether there is any difference in geological age of these rocks is not yet satisfactorily determined. Dr. E. Hussak, in a purely petrographic paper, "Grünstein-trachyte oder Propylite," published in the same journal, states that the rocks are much decomposed and agrees with Zirkel as to their microscopical habitus. He says: "Diese Gesteine ähneln den alten sogenanten Dioritporphyren wie auch den Diabas-porphyriten ungemein, sind jedoch mit den tertiären Eruptivgesteinen eng verknüpft und wohl nicht davon zu trennen." See also Prof. J. W. Judd's valuable paper "On the Ancient Volcano of the District of Schemnitz, Hungary," Quar. Jour Geol. Soc., August, 1876.

Unless erosion at Schemnitz, unlike the conditions at Washoe, has worn away the greater part of the superincumbent rock, we are led to believe, without any personal acquaintance with the district, that a thorough investigation of a large number of thin sections prepared from judiciously selected rocks would show a complete transition from the glassy volcanic lavas to those corresponding in texture to crystalline diorite or diabase.

out its whole length it was not originally a pyroxene-andesite. Wherever the rock occurs sufficiently fresh to allow a close study its identification with this type of andesite seems established. All these facts convince us that the Comstock lode cannot be considered as a contact vein between two different rock masses.

Owing to the intimate connection between hornblende and augite, and the fact that pyroxene-andesites with varying amounts of hornblende occur, indistinguishable from many hornblende-andesites with more or less pyroxene, it is impossible to draw a sharp line of demarcation between the two types. Great confusion arises when we undertake to map out the Washoe district, where both rocks occur in every possible gradation between the two specific types. Such transitions were recognized by Mr. Becker, who, having outlined the different areas covered by the different volcanic masses according to geological age, often considered himself forced to determine a rock quite as much from its occurrence within certain areas as from its mineral composition, regarding the variations as local modifications.

In general the hornblende-andesite here, as in many other districts, seems to be more silicious than the pyroxene types, yet analyses show many marked exceptions. In the intermediate volcanic rocks, like those which make up the greater part of the mass at Washoe, where the range in chemical composition between the two is so slight, a variation in mineral composition may easily take place.

Doubtless much of the confusion which exists in the Washoe district between the hornblende and pyroxene divisions of these rocks arises from the cutting of one rock by the dikes of the other in a far greater degree than has been heretofore recognized. Indeed, the region is penetrated by broad fissures and narrow dikes, varying in width from many hundred feet to those exposing only a few feet where cut by mining shafts and levels.

This is especially noticeable in the Sutro tunnel, which, after passing through the broad belt of hornblende-mica-andesite, enters, as has been already mentioned, a vast body of pyroxene-andesite forming the main rock mass as far as the tunnel runs. All other bodies, both large and small, cut by the tunnel present the appearance of occurring as dikes, many of them failing to reach the surface. These facts lend support to the theory that a large body of pyroxene-andesite forms the older and central mass of the mountain. At 17,100 feet from the mouth of the tunnel a remarkably fresh hornblende-andesite is cut with every indication, judging from the specimens, that it occurs as a dike. It seems quite possible that this may have served as a vent through which was extruded, a portion at least, of the hornblende rock found on the surface along the east base of Mount Davidson.

In the subjoined table are presented a series of twelve chemical analyses representing the principal variations in composition and structure of the volcanic rocks found at Washoe.

TABLE IV.—*Chemical analyses.*[1]

Number.	Determination.	Locality.	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	CaO	MgO	Na_2O	K_2O	Other components.	Ignition.	Total.	Analyst.
I	Basalt	North of American Flat Creek.	47.91	2.70	14.26	1.65	7.80	trace	9.60	10.83	3.01	1.89	Li_2O . trace	0.37 H_2O	100.02	Samuel L. Penfield.
II	Granular pyroxene-andesite.	Eldorado outcrop	56.71	......	18.36	......	6.45	......	6.11	3.92	3.52	2.38	....	1.94 H_2O	99.39	R. W. Woodward.
III	Pyroxene-andesite	Sutro tunnel, foot-wall, Savage connection.	56.40	1.14	15.99	3.26	3.82	0.12	6.98	3.54	3.83	1.91	P_2O_5 .. 0.32	2.47	99.78	Gideon E. Moore.
IV	Hornblende-andesite	Center of Cedar Hill ridge.	58.55	0.83	15.48	3.93	2.07	0.11	6.44	3.60	3.99	1.69	P_2O_5 .. 0.30	3.62	100.61	Do.
V	Pyroxene-andesite (hornblende bearing).	Ridge northeast of American Flat.	58.44	......	18.17	......	6.03	......	6.19	2.40	3.20	1.97	Co_2.... 2.87	0.76	100.03	W. G. Mixter.
VI	Pyroxene-andesite (hornblende bearing).	Silver terrace	59.22	......	18.20	......	6.69	....	5.51	2.90	3.81	1.39	....	2.80 H_2O	100.02	Do.
VII	Hornblende-andesite	Cross Spur quarry below Graveyard.	60.82	......	17.54	......	5.42	......	5.65	1.76	3.71	1.41	Co_2.... 1.41	2.31	100.13	Do.
VIII	Hornblende-mica-andesite.	Mount Rose	63.30	......	17.81	3.42	0.83	......	5.12	2.07	4.27	2.26	Li_2O . trace	0.88 H_2O	99.96	R. W. Woodward.
IX	Hornblende-mica-andesite.	Cross Spur quarry	63.13	......	16.00	4.34	1.52	.....	4.45	2.07	3.87	2.65	....	2.00 H_2O	99.54	Do.
X	Mica-andesite	800′ east of Waller Defeat shaft.	65.68	0.98	15.87	1.78	1.25	......	3.50	1.79	3.20	3.37	P_2O_5 .. 0.23	3.10	100.75	Gideon E. Moore.
XI	Dacite	Spur northeast of McClellan Peak near American Flat road.	69.96	.....	15.79	2.50	.....	......	1.73	0.64	3.80	4.12	....	1.53	100.07	F. A. Gooch.
XII	Rhyolite	South-southeast of McClellan Peak.	73.07	......	11.78	2.30	......	......	2.02	0.39	1.19	6.84	....	2.24	99.83	Do.

Number.	Designation in Mr. Becker's report.	Designation in Mr. King's report.	Number of thin section	Number of specimen.	Number.	Designation in Mr. Becker's report.	Designation in Mr. King's report.	Number of thin section.	Number of specimen.
I	....	Basalt	*528	22647	VII	Hornblende-andesite	Propylite	*231	22717
II	Diorite	Diorite	(*)	22615	VIII	Later hornblende-andesite	Trachyte	*283	22631
III	Earlier diabase	....	18	270	IX	Later hornblende-andesite	Trachyte	*284	22637
IV	Porphyritic diorite	....	421	482	X	Mica-diorite	....	101	506
V	Augite-andesite	Hornblende-andesite	(*)	22719	XI	Quartz-porphyry	....	496	231
VI	Augite-andesite	Hornblende-andesite	*832	22706	XII	Quartz-porphyry	....	495	249

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[1] These analyses have been revised by comparison with the original records so far as possible; those which were found to be from much decomposed rocks have been omitted.

[*] The numbers marked with an asterisk are from the collection of the Fortieth Parallel Exploration; the remainder are from Mr. Becker's collection.

They are mainly compiled from the table published in Mr. Becker's monograph and revised as far as possible by comparison with the original records. They are here arranged according to their acidity in order to bring out forcibly the great similarity existing in chemical composition between rocks which we have endeavored to show were identical in mineral composition and structural features. Numbers I, XI, XII, the extreme basic and acidic varieties of the series, are now published for the first time. The identity in composition of the hornblende and pyroxene-andesites, which make up the central mass of the mountain, is shown in analyses II to VII, inclusive, the extremes in silica (with a variation of a little more than 4 per cent.) lying quite within the range of most volcanic extrusions. Between the coarse-grained rock from Eldorado outcrop (II), representing the mass of Mount Davidson, and the coarse-grained pyroxene-andesite (III) from the Sutro tunnel, near the Savage connection, chemical analysis fails to detect any marked difference; while between the so-called porphyritic diorite (IV) and hornblende-bearing pyroxene-andesites the variations are such as might occur in different parts of the same volcanic flow. In a well characterized hornblende-andesite from the Cross-Spur quarry (VII) the silica reaches 60.82 per cent.

In order to strengthen and confirm these analyses silica determinations have been made of several rocks from other localities in the district, carefully selected to represent the same range in mineral composition. Those agreeing in the preponderance of hornblende or pyroxene are placed together as follows:

1. Pyroxene-andesite (granular diabase), 56.40 per cent. SiO_2.
2. Pyroxene-andesite (augite-andesite), 56.56 per cent. SiO_2.
3. Hornblende-andesite (porphyritic diorite), 55.66 per cent. SiO_2.
4. Hornblende-andesite (hornblende-andesite), 55.79 per cent. SiO_2.
5. Hornblende-andesites (hornblende-andesite), 57.06 per cent. SiO_2.

They all occur near the base of Mount Davidson from the following localities:

1. Ophir ravine, southeast of Cole water tunnel.
2. 1,000 feet due west of quarry above Occidental grade.
3. Ophir ravine, southeast of Cole water tunnel.
4. Ridge north of Ophir Hill, 150 feet west of old flume.
5. Tank 600 feet northwest of Yellow Jacket shaft.

From these it will be seen that the pyroxene-andesite from Ophir ravine is identical in silica percentage with the foot-wall, Savage connection in the Sutro tunnel, and differs from the pyroxene-andesite of the surface by only 0.16 per cent. of silica. The hornblende-andesite from near the Cole water tunnel differs from that of the ridge near Ophir Hill by 0.13 per cent. of silica. The refinements of chemistry like those of the microscope fail to detect any distinctions between the rocks of the same mineral composition, which have here been classed as Tertiary and Pre-Tertiary age.

We turn now to the later rock masses of both acidic and basic character found penetrating the main body of hornblende and pyroxene andesite of intermediate composition. We will first consider the hornblende-mica-andesites (later hornblende-andesite and mica-diorite), which, though presenting variations from a porphyritic lava with a glassy and microlitic groundmass to a granular structure recognized by the unaided eye, have already been shown to be indistinguishable petrographicly. An examination of the specimens shows that it is the coarsely crystalline and decomposed middle-grained varieties which have been classed as Pre-Tertiary rocks, while the fresh and unaltered middle-grained and the glassy ones were regarded as of Tertiary age. The broad high ridge, lying to the eastward of Mount Davidson, of which Mount Rose and Mount Kate are conspicuous features, forms the principal mass of this rock breaking through the pyroxene-andesite. Upon the slopes of the ridge a considerable variation in texture of the rock is easily recognized. It is only on the surface along the ridge that glassy forms are met with. Comparing the hornblende-mica-andesite exposed through the 10,000 feet cut by the Sutro tunnel with the surface rocks, exact counterparts are observed with the exception that glassy forms are wanting. This is, however, what we should expect, and quite in accord with all the observations so far made upon the collections from Washoe, namely, that the glassy forms of the various rocks are only found at or near the surface, those from any considerable depth having cooled with sufficient slowness to become holocrystalline. Advancing now a step further we find that the more crystalline rock from this large body of hornblende-mica-andesite bears the closest resemblance to parts of the so-called Pre-Tertiary mica-diorite, which passes, as has already been shown, by imperceptible gradations into rock possessing a granular structure.

Let us consider in this place what the intermediate forms are which link together rocks of the chemical composition of a glassy hornblende-mica-andesite possessing all the characteristics of a surface lava with those having the structure of many granitic rocks. The results derived from a study of numerous rock sections[25] clearly indicate that the essential variation in the more porphyritic varieties takes place in the groundmass, which, starting with glass containing few microlities, gradually grows richer and richer in microlitic inclusions until only a small amount of glass remains as a cementing base. This in turn may be crystallized into microscopically cryptocrystalline particles. In a somewhat more advanced stage the cementing material assumes the appearance of uniformly oriented patches or of microcrystalline granitoid grains, which as the size of the grain increases is found to be partly quartz, partly feldspar. The dimensions of the cemented microlites also increase until they appear as small crystals embedded in a mass of irregularly shaped grains of feldspar and quartz. As the number of large crystals and those of medium size increases the porphyritic appearance of the rock is lost, especially as the sharp outline of the larger crystals is no longer preserved, as already described. The character also of the feldspars changes by reason of the variation in their inclusions, those of glass growing less numerous as the rock becomes more crystalline, until they disappear entirely, occasional fluid inclusions making their appearance. When finally the grains are nearly all of one size the structure is the even granular one of a granite.

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[25] See Table III; also Table I.

Quartz, which in the glassy forms of these hornblende-mica-plagioclase rocks occasionally is seen in small porphyritic grains, first makes its appearance as an essential ingredient among the microscopic grains of the groundmass, becoming more and more apparent as their size increases. This quartz contains in the coarser-grained forms numerous fluid inclusions, indicating that the gases disseminated through the magma, having been excluded by the first crystallizing minerals, were finally inclosed in the quartz, the last mineral to crystallize, which would necessarily occur when a magma consolidates under pressure, the gases being unable to escape. The number of mineral constituents is still further increased by the development of acidic feldspars, the uncrystallized material of which, together with the silica of the quartz, makes up the residual glass base of the vitreous forms of the rock. It has already been shown[26] that the glass of a vitreous lava grows richer in silica and alkalies as the more basic minerals crystallize out of the magma.

Thus the rock which in a vitreous state is composed essentially of basic feldspar, hornblende, and mica, with a groundmass of glass more or less full of microlites, is, when coarse-grained, formed of both basic and acidic plagioclase with some orthoclase, besides hornblende, mica, and quartz—the mineral composition of a quartz-diorite. The best examples of this decidedly granitic structure are from the 1,000-foot level of the Sierra Nevada and the shaft of the Lady Bryan mine, rocks which some geologists would call hornblende-bearing granite, but to which Mr. Becker refers in his monograph[27] as "fresh, coarsely granular, quartzose diorite." Though we know but little of the actual occurrence and field relations of the rocks represented by these two specimens, one coming from the end of a drift and the other collected from the dump of a mine, still it is noteworthy that they both come from the immediate neighborhood of the most extensive area of hornblende-mica-andesite in the district, and though geological evidence of their direct connection is wanting, the chain of petrographic evidence is so complete as to leave no doubt in our minds that these coarsely granular rocks are parts of the same magma as the hornblende-mica-andesites which have crystallized very slowly under considerable pressure.

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[26] F. Fouqué, "Santorin et Ses Éruptions," Paris, 1879, p. 11. Hague and Iddings, "Notes on the volcanoes of Northern California, Oregon, and Washington Territory," Am. Jour. of Science, Vol. XXVI, Sept., 1883, p. 230.

[27] Geology of the Comstock Lode, page 192.

With the exception of one body near the north end of the vein, the so-called mica-diorite only occurs on the surface, as shown on the map,[28] in a few isolated patches of no great elevation, where it presents the appearance of having broken through the andesite. That there is good reason for such a conclusion is borne out by the strongest geological evidence beneath the surface. It has been pointed out that the andesite of the Sutro tunnel is cut in three places by narrow dikes of hornblende-mica-andesite of a medium crystallization, showing that here at least a similar rock is younger than the main body of Tertiary andesite.

Other instances of this hornblende-mica-rock cutting the pyroxene-andesite are shown in the vertical sections through the Yellow Jacket and Belcher mines (atlas sheet VII), and can only be reasonably explained as dikes and offshoots from the main body of a later rock penetrating an older one. By reference to the geological map it will be seen that the Forman shaft is located in andesite between two small outcrops of hornblende-mica-rock only 3,500 feet apart. Now the fact that the shaft has been sunk for a depth of 2,340 feet without encountering either body seems to point to the conclusion that these hornblende-mica rocks are simply dikes cutting the andesite.

Let us consider one more fact. On the 1,950-foot level of the Utah mine a narrow body of medium-grained hornblende-mica rock is exposed penetrating the pyroxene-andesite. Now this small body is vertically beneath the later hornblende-mica-andesite of the surface, with the evidence all tending to the conclusion that the two bodies are closely connected masses.

Such geological evidence as to the position of these rocks seems all-sufficient to determine their age, but taken in connection with the proof of identity afforded by rigid petrographic analysis the arguments appear indisputable.

As already mentioned, the hornblende-mica rocks vary considerably in their mineral composition within certain limits, and a corresponding variation is observed in their chemical composition. Analyses VIII and IX (Table IV) are from the hornblende-mica-andesites of Mount Rose and Cross Spur quarry, which are rich in iron magnesia silicates, hornblende being in excess of mica in one case and equaling it in the other. Analysis X from the "mica-diorite," 800 feet east of the Waller Defeat shaft, shows less iron and magnesia, which corresponds to the small amount of iron and magnesia silicates found in the rock, mica greatly predominating over hornblende. It represents one of the most acidic of these hornblende-mica rocks.

The quartzose Tertiary rocks, as has been shown, belong both to dacite and to rhyolite, the rocks intermediate between the two being well developed. The surface area covered by them lies wholly in the southern and southeastern portion of the district, mainly in the neighborhood of American Flat. Their geological position is best observed in the underground workings to the north, where the main body of pyroxene-andesite occupies the surface, and although the number of exposures is limited, their evidence is clear. No stronger proof can be desired of the Tertiary age of the rocks in question than the occurrence in the Sutro tunnel of a broad dike, 1,400 feet in width, with numerous offshoots cutting the main body of pyroxene-andesite. Microscopical examination proves this rock to be the counterpart of a lithoidal variety found on the surface near Gold Cañon and the Red Jacket mine.[29] In the Overman mine a dacitic or rhyolitic rock apparently occurs as a narrow dike extending upward nearly to the surface from the 2,000-foot level. Again the occurrence in the Belcher mine can best be explained on the simplest and most plausible theory of an offshoot or stringer from the main mass. The Forman shaft, after passing through pyroxene and hornblende-andesite, exposes at about 2,340 feet from the surface a small body determined by Mr. Becker as an orthoclase rock, which he classes as quartz-porphyry. Although our knowledge of the body is extremely limited, there seems to be every reason, judging from analogy, that it also occurs as an intrusive mass penetrating the andesite but failing by many hundred feet of reaching the surface. It is worthy of note that the rock is holocrystalline and presents certain characteristics common to igneous rocks cooled at considerable depths below the surface, and which many geologists regard as evidence of their Pre-Tertiary age.

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[28] Geology of the Comstock Lode, Atlas, Sheet IV.

A recent analysis in the laboratory of the United States Geological Survey, by Dr. F. A. Gooch, of a dacite from near McClellan Peak, is given in Analysis XI (Table IV). It will be noticed that the potassa is but slightly in excess of the soda, and the miscroscope shows that the plagioclase is far in excess of orthoclase among the porphyritic crystals. In Analysis XII, also by Dr. Gooch, the potassa greatly predominates over soda, and the rock from which it was made is characterized by prevailing orthoclase, the habitus and chemical composition being those of a typical rhyolite.

Geological evidence having proved that the rock penetrated by the black dike is inseparable from the Tertiary pyroxene-andesite lavas, it of course follows that the later rock is also of Tertiary or still more recent age. A comparative study of the hand specimens and their sections has shown the similarity in composition and structure existing between the surface basalts, near American Flat, and the well-known black dike of the Comstock lode, they differing only slightly in degree of crystallization and state of preservation. By reference to the map (atlas sheet IV) it will be noticed that there are only five surface occurrences of basalt, all of them insignificant in area and in height. In a direct line from the basalt masses, immediately to the westward of American Flat, it is only 4,500 feet to the Caledonia shaft, where the black dike is last seen along the line of exploration on the Comstock.

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[29] Compare the following hand specimens: Numbers 182 to 192 from the Sutro tunnel with 417, 370, 397, 399, 405, and 411 from the surface collection.

The chemical composition of the surface basalt is given in Analysis I (Table IV). It is somewhat basic, but in other respects is quite similar to many of the basalts of the Great Basin. The basalt of the black dike from the Belcher mine, 1,145 feet below the surface, yielded 49.79 per cent. of silica, the difference between the two analyses being quite within the range of variation for the same flow. Now, although the black dike forms the only dike of basalt known in the district, and its direct connection with the small surface patches has never been traced, the evidence is quite sufficient to lead to the conclusion that it, like the intrusive bodies of hornblende-mica-andesite, dacite, and rhyolite, is an offshoot from a much larger mass at no great distance.

CONCLUSIONS.

As stated in the first part of this paper our investigation leads us, in many important particulars, to conclusions in respect to the geological structure of the Washoe district quite at variance with the opinions held by our predecessors. Throughout the body of the paper we have endeavored to place before the reader with considerable detail the facts upon which our opinions were based. Let us then in reviewing these results state in a few words what we consider to be the geological history of Washoe and the relations of the principal rock masses and intrusive bodies to each other, and then briefly summarize the conclusions maintained in this discussion as to the development of crystallization in the igneous extrusions which have built up this mountain pile.

We regard the main mountain mass of which Mount Davidson is the culminating peak to be formed of both pyroxene- and hornblende-andesites, of much the same ultimate chemical composition, analyses showing a variation of only 4 per cent. in silica. Both these types of andesite are so intimately connected geologically with each other as to render it extremely difficult to separate them on a basis either of physical structure or of geological age. So long as the conditions under which hornblende and pyroxene are formed in lavas of this class are so little understood it becomes a difficult matter at Washoe to determine with precision the relations of andesitic eruptions based solely upon these minerals. The fact, however, that the main mass of Mount Davidson is made up of coarsely crystalline material originally a pyroxene rock, and that the section through the Sutro tunnel after leaving the hornblende-mica-andesite body of Mount Rose and Mount Kate runs mainly through pyroxene-andesite, makes it highly probable that the earlier and larger part of the eruption was composed of this rock. Through this pyroxene-andesite hornblende-andesite is known to penetrate, and observations all point to the conclusion that vents have been opened through which both types of rock have been forced upwards, although not necessarily reaching the surface.

After these eruptions of pyroxene and hornblende andesites there was a period of rest, during which there was more or less removal of the superficial material by denudation, a study of the surface geology presenting many arguments in favor of a time of comparative inaction. These older andesitic rocks have been broken through by numerous intrusive bodies of both acidic and basic lavas represented by hornblende-mica-andesites, dacites, rhyolites, and basalts. From masses of these later rocks offshoots were pushed out and forced upwards into the older rocks, in many cases failing to reach the surface, but now exposed by vertical shafts and horizontal workings.

We find the glassy forms of these rocks only on or near the surface. Rocks from the tunnels and mining shafts from any considerable distance beneath the surface present invariably a holocrystalline structure, while the more coarsely crystalline forms come from near the central mass, from intrusive dikes, or are brought up from the lowest depth reached by mining shafts. It is not of course to be expected that development in crystallization should show an unvarying increase in any given direction through a rock mass. On the contrary, changing conditions would necessarily bring about more or less local modifications. Variations in rapidity of cooling or amount of pressure would produce local centers of crystallization, with corresponding variations in rock structure. Moreover the degree of crystallization developed in different lavas under similar conditions appears to depend upon their chemical composition, the basic lavas showing a greater tendency to crystallize than the acidic.

When we consider the evidence offered by the 4 miles of the Sutro tunnel, the vertical sections 3,000 feet in depth, and the network of long galleries run at different levels from the main shafts, the innumerable facts, all pointing in one way, present such overwhelming proof that we are led to the conclusions maintained in this paper, and briefly summed up as follows:

That the degree of crystallization developed in igneous rocks is mainly dependent upon the conditions of heat and pressure under which the mass has cooled and is independent of geological time.

That there are abundant geological and petrographic evidences in the Washoe district to show that the igneous rocks do not belong partly to Pre-Tertiary and partly to Tertiary eruptions, but are all of Tertiary age.

That the so-called granular diorite and diabase, augite-andesite are identical and belong to the same geological body.

That the so-called porphyritic diorite is identical with hornblende-andesite and should be designated by the latter name.

That the so-called mica-diorite is identical with the later hornblende-andesite and both rocks are of the same geological age.

That the quartz-porphyry is of Tertiary age and resolves itself into both dacite and rhyolite.

That the later diabase or black dike and the basalt are one and the same rock, the difference being that the former is only known as a narrow dike while the latter occurs in flat-topped bodies and low hills on the surface.

That the Comstock lode occupies a fissure along a line of faulting in rock of Tertiary age, and cannot be considered as a contact vein between two different rock masses.

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IN

[illegible] Wm E. Brenner
with compliments of
the author

OF THE

UNITED STATES

GEOLOGICAL SURVEY

No. 18

ON MARINE EOCENE FRESH WATER MIOCENE AND OTHER
FOSSIL MOLLUSCA OF WESTERN NORTH AMERICA

WASHINGTON
GOVERNMENT PRINTING OFFICE
1885

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[Bulletin No. 18.]

The publications of the United States Geological Survey are issued in accordance with the statute, approved March 3, 1879, which declares that—

"The publications of the Geological Survey shall consist of the annual report of operations, geological and economic maps illustrating the resources and classification of the lands, and reports upon general and economic geology and paleontology. The annual report of operations of the Geological Survey shall accompany the annual report of the Secretary of the Interior. All special memoirs and reports of said Survey shall be issued in uniform quarto series if deemed necessary by the Director, but otherwise in ordinary octavos. Three thousand copies of each shall be published for scientific exchanges and for sale at the price of publication; and all literary and cartographic materials received in exchange shall be the property of the United States and form a part of the library of the organization: And the money resulting from the sale of such publications shall be covered into the Treasury of the United States."

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ANNUAL REPORTS.

Of the Annual Reports there have been already published:

I. First Annual Report to the Hon. Carl Schurz, by Clarence King. 1880. 8°. 79 pp. 1 map.—A preliminary report describing plan of organization and publications.

II. Report of the Director of the United States Geological Survey for 1880-'81, by J. W. Powell. 1882. 8°. lv, 588 pp. 61 pl. 1 map.

III. Third Annual Report of the United States Geological Survey, 1881-'82, by J. W. Powell. 1883 8°. xviii, 564 pp. 67 pl. and maps.

IV. Fourth Annual Report of the United States Geological Survey, 1882-'83, by J. W. Powell. 1884. 8°. xii, 473 pp. 85 pl. and maps.

The Fifth Annual Report is in press.

MONOGRAPHS.

Of the Monographs, Nos. II, III, IV, V, VI, VII, and VIII are now published, viz:

II. Tertiary History of the Grand Cañon District, with atlas, by Clarence E. Dutton, Capt., U. S. A. 1882. 4°. xiv, 264 pp. 42 pl. and atlas of 24 sheets folio. Price $10.12.

III. Geology of the Comstock Lode and the Washoe District, with atlas, by George F. Becker. 1882. 4°. xv, 422 pp. 7 pl. and atlas of 21 sheets folio. Price $11.

IV. Comstock Mining and Miners, by Eliot Lord. 1883. 4°. xiv, 451 pp. 3 pl. Price $1.50.

V. Copper-bearing Rocks of Lake Superior, by Roland D. Irving. 1883. 4°. xvi, 464 pp. 15 l. 29 pl. Price $1.85.

VI. Contributions to the Knowledge of the Older Mesozoic Flora of Virginia, by Wm. M. Fontaine. 1883. 4°. xi, 144 pp. 54 l. 54 pl. Price $1.05.

VII. Silver-lead Deposits of Eureka, Nevada, by Joseph S. Curtis. 1884. 4°. xiii, 200 pp. 16 pl. Price $1.20.

VIII. Paleontology of the Eureka District, by Charles D. Walcott. 1884. 4°. xiii, 298 pp. 24 l. 24 pl. Price $1.10.

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UNITED STATES GEOLOGICAL SURVEY
J. W. POWELL DIRECTOR

ON

MARINE EOCENE FRESH WATER MIOCENE

AND OTHER FOSSIL MOLLUSCA

OF

WESTERN NORTH AMERICA

BY

CHARLES A. WHITE M. D.

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ON FOSSIL MOLLUSCA OF WESTERN NORTH AMERICA.

By CHARLES A. WHITE

THE OCCURRENCE OF CARDITA PLANICOSTA LAMARC IN WESTERN OREGON.

There is probably no species among all the known fossil mollusc concerning the geological age of which paleontologists are more in accord than *Cardita planicosta* Lamarck. It is a well-known form in th European Eocene, and it is quite as characteristic of the Eocene of ou Atlantic and Gulf borders as of the Eocene of Europe. The Europea and the American specimens differ so little from each other that no on now pretends to question their specific identity. Both the Europea and the American strata furnish specimens of this species in abundance and great perfection, so that all the characteristics of the shel are well known. Its range of variation is not great, being mainly apparent in the extent of the obliquity of the axis and in the varyin distinctness of definition of the ribs and their interspaces. In som cases the ribs upon the anterior part of the shell are broadly conve and the interspaces there are narrow and not sharply defined from th ribs at their sides. In the case of a few examples these characteristic are found to extend to other parts of the shell, but usually the ribs ar more flattened and the interspaces are in the form of more or les sharply defined grooves between the ribs. In some cases the ribs an separating grooves are distinctly defined all the way from the beaks t the free borders of the valves; but in others the ribs and grooves, whil they are well defined upon the umbonal and median portions of th valves, become obsolete before reaching their free borders. The character of the variation to which the surface markings of this species ar thus seen to be subject is such that if it becomes excessive in any grou of examples it is suggestive of a specific difference. The hinge is massive and constant in its characteristics.

Mr. Conrad recognized this species among the collections which wer obtained some thirty years ago, by parties connected with the Pacif Railroad surveys,[1] from strata in California which have since receive the name of the Téjon group. This group was referred to the Cretaceous period by the geologists of the State Geological Survey of California, but I have elsewhere given my reasons for regarding it as of Eocene age,[2] as Conrad, Marcou,[3] Heilprin,[4] and others have also done. The California *Cardita* just referred to, Mr. Gabb regarded as specifically distinct from *C. planicosta*, and he gave it the name of *C. hornii*.[5] I have seen only fragments of the California form, but judging from these and Mr. Gabb's description and figures I am inclined to regard it as a variety of *Cardita planicosta*, differing from the typical form only in the unusual broad convexity of all, instead of a part, of its ribs. The difference between the California specimens and the typical form of *C. planicosta*, as was shown by Mr. Gabb, consists mainly or wholly in this character of the ribs and their interspaces, and this I believe to be a case of extreme variation of *Cardita planicosta* which is not incompatible with specific identity.

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[1] See Pacific Railroad Reports, Vol. V, pp. 317–329.

Some specimens of *Cardita* which I am unable to distinguish specifically from *C. planicosta* have been lately received at the office of the Survey which were obtained from strata that are perhaps equivalent with those which bear *C. hornii*, and which appear to me to be intermediate between typical examples of that species and *C. hornii*. These specimens were collected by Prof. Thomas Condon, at the town of Albany, in the Willamette Valley, Oregon. They are numbered 13405 in the Catalogue of the U. S. National Museum. The stratum which contains these shells is an indurated dark colored shale, which was found a few feet beneath the surface of the ground in digging a cistern at Albany.

Unfortunately neither this stratum nor any known equivalent of it has been recognized elsewhere, and as the stratum was not exposed at the surface where the discovery was made, and the digging was not continued through it, nothing is definitely known of its stratigraphical relations. Strata which bear characteristic Miocene fossils are found in the valley of the Willamette only a few miles away, but so far as I am aware no strata have hitherto been found in any part of Oregon which bear *Cardita planicosta*, nor any nearly related form. Unfortunately, also, although a dozen or more of the shells of the *Cardita* were obtained, only a few fragments of other shells were found associated with them. Some of these apparently represent a species of *Crassatella*, but further than this they have yielded no definite information.

Three of the valves found at Albany are represented on Plate I. These specimens have been chiseled out of the matrix in which they were embedded, and their natural surface has therefore been somewhat injured, but enough remains in its natural condition to give a fair illustration of the surface characters of the shell. The vertical diameter of two of these illustrated specimens is proportionally less as compared with the transverse diameter, than is usual with typical examples of *C. planicosta*, but that of one of them is not, and several of the other associated specimens have also the usual dimensions. None of the Oregon specimens show the hinge in a sufficiently perfect condition to afford a good figure of it, but some of them exhibit the hinge characters so plainly as to make it evident that this far western shell does not differ in respect to the hinge from the typical examples of *Cardita planicosta*. I do not therefore hesitate to refer it to that species.

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[2] See Bull. U. S. Geol. Survey, No. 15.

[3] See Bull. de la Société Géologique de France (3), T. XI, 1883, pp. 407–435.

[4] Proc. Acad. Nat. Sci. Phila. for 1882, pp. 195–214; also Cont. Ter. Geol. and Paleont. U. S., pp. 102–116.

[5] Paleontology of California, I, p. 174, Pl. 24, Fig. 157; also II, p. 187, Pl. 30, Fig. 83.

The discovery of these shells in Western Oregon possesses more than ordinary interest for several reasons. First, it adds materially to our knowledge of the already known wide geographical range of *Cardita planicosta*. Second, it is (if we except the *Cardita hornii* of Gabb) the first recognition of that species in the Pacific coast region that has been made. Third, *Cardita planicosta* being regarded by all paleontologists as of Eocene age, its discovery in Oregon indicates the existence there of the Eocene formation, of which no other indication is now known. It is not improbable that the stratum from which these fossils were taken represents a portion of the Téjon group of California. No evidence of it, however, is at present known other than that which is suggested in the preceding paragraphs and by the probability that the Oregon specimens and the *C. hornii* of Gabb are only varieties of *Cardita planicosta.*

FOSSIL MOLLUSCA FROM THE JOHN DAY GROUP IN EASTERN OREGON.

Some two years ago Prof. E. D. Cope placed in my hands a small collection of fossil mollusks, which were obtained by Mr. Jacob L. Wortman, of the Army Medical Museum, from a lacustrine deposit in Eastern Oregon which has come to be known as the John Day group. Professors Leidy,[6] Marsh,[7] and Cope[8] have described vertebrate fossils from that deposit, which has been referred by those authors to the Miocene; and by Professors Leidy and Cope it has been regarded as equivalent with the White River group of Dakota. Mr. King regarded it as equivalent with his Truckee group,[9] which occurs in the valley of Snake River, in Southeastern Oregon, and also in Northern Nevada.

Last summer, also, Prof. Thomas Condon, of the University of Oregon, presented to the Survey a small collection of shells which he obtained from the John Day group at or near the same locality as that from which Professor Cope obtained his specimens. Professor Condon found those shells associated with the vertebrate fossils which were described by Professor Leidy (*loc. cit.*), and Mr. Wortman also found the mollusks associated in the same layers with the vertebrate remains. Upon Prof. Condon's label accompanying these shells he designates the locality as "the North Fork of John Day River, Oregon, at the angle of the big bend, longitude 119° 40′, latitude 44° 50′. Professor Condon's collection embraces the same species which Professor Cope's contained, but no others.

These collections contain one, and perhaps two, species of *Unio* and four or five species of pulmonate gasteropods, which latter I refer to the Helicidæ; but no other invertebrate forms were found associated with them. The John Day deposit being of lacustrine origin one could not expect to find it containing the remains of an extensive molluscan fauna, as compared with the faunas of marine deposits; but these small collections do not embrace so wide a variety of forms as lacustrine faunas usually present. No gill-bearing, nor palustral pulmonate gasteropods are found among them, and all bivalve mollusks, except the Uniones which have just been mentioned, are also absent. It is therefore quite apparent, from a zoological point of view, that these collections represent only a part, and probably only a small part, of the land and fresh water molluscan fauna which existed in and about the lake in which the John Day strata were deposited.

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[6] See Vol. I, U. S. Geol. and Geog. Survey of the Terr., 1873.

[7] See American Journal of Science, Vol. IX (3), p. 52.

[8] See Vol. III, U. S. Geol. Survey of the Terr., 1884.

[9] See U. S. Geol. Expl. 40th Parallel, Vol. I, p. 423.

The Uniones of these collections are of the plain oval, unornamented type, such as is common to the fresh-water deposits of all the epochs from the Cretaceous period to the present time. The land snails, which are represented on Plate III, are not only of modern types, but at least three of the species are, in my opinion and that of Dr. R. E. C. Stearns, too near like living forms to warrant one in giving them new specific names.

It is so apparent, from the evidence furnished, that these fossil forms represent the living species ancestrally that one may reasonably make the same use of them, with reference to their genetic history, as if the continuity of that history were known by actual observation. These forms, whose genetic history and specific identity have so evidently been continued in unbroken lines from the John Day epoch to the present time, have endured remarkable vicissitudes of physical conditions as well as considerable geographical dispersion since Miocene time. Some of the changes which have taken place in that region since then are very remarkable. One of the greatest volcanic outflows which the earth has known, covering thousands of square miles with melted rock and forming the great mountains of the Cascade range, occurred in and near that region since those mollusks lived upon the borders of the John Day lake. The Glacial epoch has come and gone since then, and an immense subaerial erosion has taken place over the whole region, the extent of which one cannot comprehend without witnessing its results. Not a mammalian species or genus now exists indigenously upon the North American continent that existed then, and all other vertebrate forms of continental life have materially changed; but living descendants of those land snails are thriving to-day in the same region and under the same specific forms that their remote ancestors bore.

The Truckee group, which King referred to the Miocene, and which has already been mentioned, also contains a small molluscan fauna all the members of which belong to other families than those which are represented by the mollusca of the John Day deposit which are at present known.[10] It may be that none of the species which are known to exist in one of these groups will ever be found in the other; but that representatives of the families which are missing from each may yet be found in the other is to be expected, because those missing families are such as are usually represented in lacustrine waters. The probabilities that the land mollusca of the John Day deposit may yet be found in the Truckee and other Miocene deposits of Western North America are, in my opinion, greater than that any of the gill-bearing mollusca of one should be found in the other if, as is supposed, those deposits were formed in separate hydrographic basins; because the distance between those supposed basins was not so great as to prevent the free dispersion of land mollusks across the intervening space.

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[10] See Proc. U. S. Nat. Museum, V, pp. 99-102, Pl. V; also Third Annual Report of the U. S. Geological Survey, Pl. XXXII.

It is true that the fauna of the Truckee group contains types of gill-bearing mollusca which are now extinct upon this continent; but this does not necessarily prove that it is older than the John Day fauna, because a considerable part of the living fresh-water types of North American mollusks are known to extend back to much earlier epochs.[11] I have elsewhere shown the probability that the latter had direct and continuous fluvatile habitat from those early times to the present, while the Truckee fauna probably lived in a lake whose waters were not continued in fluvatile streams to the present time, as other lacustrine waters were, after they had ceased to exist as a lake by the deepening of its outlet. The Truckee hydrographic basin, with its gill-bearing molluscan fauna, was probably destroyed as a result of the changes which attended the great volcanic outflows which have just been referred to, while contemporaneous, and even older, lacustrine waters, further eastward, were perpetuated in a fluvatile condition to the present time.

Whether the John Day, Truckee, and other lacustrine deposits which have been referred to the Miocene epoch were all really synchronous or not, must be shown by other evidence than that which the remains of mollusca, and especially land mollusca, have yet furnished, or that they are ever likely to furnish. The facts to which I have alluded show that during a part, and probably all, of the epochs which have passed since the closing portion of the Cretaceous period, quite dissimilar gill-bearing molluscan faunas existed contemporaneously upon the North American continent, a part of which faunas were closely related to living faunas and a part were not. Therefore such dissimilarity does not necessarily prove a difference of age. Again, a considerable proportion of the fresh-water and land mollusca now living in North America belong to tpyes which have been found fossil in the later Cretaceous, earliest Tertiary, and in subsequent strata; and some of the forms which have lived in these different epochs are so nearly like living species that they cannot be satisfactorily separated from them. Therefore such forms alone cannot be relied upon to prove the synchronous origin of the formations which respectively contain them.

It is evident that ever since land mollusca existed they have been very slow to change, even as regards their specific forms, and in all those continental areas whose fluvatile systems have been preserved through a series of epochs, the fresh-water gill-bearing mollusca also have been almost as slow to change as the land mollusca have been. Although the value of the fossil remains of land and fresh-water mollusca is thus seen to be much less than that of the fossil remains of marine mollusca, as indices of the geological age of the strata containing them, they are still of much value in local geology, and they are of great importance in biological investigations.

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[11] See Third Annual Report U. S. Geological Survey, pp. 481–486.

Few as they are, the representatives of the John Day molluscan fauna, which are illustrated on Plates II and III, possess a good degree of interest in several respects. They not only all belong to types which are now living in or near the same region where the fossil forms are found, but a part of the latter are so nearly like living species that, as before said, I have not thought it advisable to separate them. The species are all different from any that have hitherto been know in a fossil condition. The extraordinary physical changes which have taken place in that region since Miocene time seem not to have interrupted the continuous existence there of the large and varied land molluscan fauna which existed in the John Day epoch. Nearly related as are these fossil forms to living land mollusca, they are found associated with mammalian remains which belong to extinct species, genera, and families, and it is therefore by means of the latter that their antiquity is shown.

UNIONIDÆ.

Genus UNIO RETZIUS.

Unio condoni, sp. nov.

(Plate II, Figs. 1, 2, and 3.)

Shell transversely subelliptical in marginal outline, short in front of the beaks, elongate, and narrowing behind them to the posterior end; valves moderately, but somewhat irregularly convex; basal margin nearly straight, but having a slight emargination a little behind the mid-length; front margin regularly rounded; dorsal margin broadly convex; posterior margin sloping backward and downward above, and narrowly rounded below; beaks broad, depressed, and situated near the front of the valves, often much eroded; umbonal region broad and prominent. Surface plain except that upon the antero-basal portion of each valve a number of crenulated radiating lines appear. (Museum No. 13404.)

Length, 90 millimeters; greatest height, 53 millimeters.

The specimens are all in a damaged condition, so that all the specific characters have not been clearly ascertained. The relative length and height of the shell appears to be subject to considerable variation, which is probably due in part to sex and in part to difference in age, the young, in all cases, having been proportionally shorter than the adult shells. A conspicuous feature of this species is its broad, prominent umbones, rising above the depressed beaks. The extensive erosion which the beaks of most of the specimens have suffered, and which evidently occurred while the animal was living, is also worthy of note.

The amount of the erosion is no greater than often occurs upon the shells of living fluvatile unios, but among the fossil species of North America eroded beaks have seldom been observed.

The specific name is given in honor of Prof. Thomas Condon, who discovered the specimens which are figured on Plate II.

HELICIDÆ.

The Helicidæ of the John Day fauna, which are mentioned in the foregoing and following paragraphs, and figured on Plate III, I submitted to Dr. R. E. C. Stearns, whose familiarity with that family, and especially as it is developed in Western North America, is well known. His comments upon the same will be found under the head of the respective species on the following pages.

Helix (Aglaia) fidelis Gray.

(Plate III, Figs. 1, 2, and 3.)

The following are Dr. Stearns's remarks upon this form:

"This fossil form at once suggests the well known and widely distributed living species *Helix* (*Aglaia*) *fidelis* Gray, of Western North America. A careful comparison of it with the very large geographical suite of that species, which includes a great number of localities within its known area of distribution, verifies the suggestion. The only objection that I can anticipate as likely to be made is that the umbilicus, in the most perfect of the fossil examples, is closed; but in the specimen referred to there is some evidence of mechanical flattening, as if by external pressure. Aside from this, a critical examination of the large suites in the United States National Museum (the Stearns collection) shows a great range of variation in that character. While in some specimens the umbilicus is widely open, in others it is so nearly covered that a slightly increased deposit of callus in the umbilical region would so completely seal it as to make it imperforate. My conclusion is that these fossil specimens may be safely attributed to *Helix* (*Aglaia*) *fidelis*." (Museum No. 13400.)

Helix (Patula) perspectiva Say.

(Plate III, Fig. 7.)

The collections contain only one example of this form, which is somewhat damaged. Dr. Stearns observes that this specimen, "in the number and closeness of its whorls and general aspect, although somewhat distorted by compression, points directly to the living species *Helix* (*Patula*) *perspectiva* Say." (Museum No. 13402.)

Helix (Monodon ?) dallii Stearns (MS.).

(Plate III, Figs. 4, 5, and 6.)

Dr. Stearns regards this form as an undescribed one, and he has accordingly furnished me with the following description of it, together with some remarks upon its nearest allies, as indicated by his large collections:

"Shell elevated, subconical, base flattened-convex, imperforate; umbilical region depressed. Lip moderately thickened and reflected. Surface traversed by fine incremental lines, and also marked by minute pits (cicatrices?) as seen under a magnifier, indicating that it had a hirsute epidermis. Whorls six to six and a half, rounded and gradually increasing. Suture quite distinct. Aperture rounded, lunate.

"Of the three specimens submitted to me for examination the foregoing description is made from the most perfect. A comparison of the three exhibits the following differences:

"Maximum height, 0.63, 0.52, 0.60 inches; maximum diameter, 0.85, 0.79, 0.85 inches. Apical angle about 95.

"Mr. Tryon, to whom I submitted this form, regards it as allied to the West Polynesian groups *Chlorea* and *Geotrochus*, and still more closely allied to the group *Artemon* of *Streptaxis*. After a careful comparison of this fossil form with the living Helices of the west coast of North America, I find that while the former is larger than any specimens of *Helix* (*Mesodon*) *columbianus* that I have seen, and differs from that species in the matter of the umbilicus, and in having a less reflected lip, in other respects it presents many of the characters of the latter, especially in the following particulars: In general aspect (size and umbilicus excepted), apical angle, when compared with elevated individuals; number of whorls and convexity of the same; sutural definition; ratio of increase in the size of the whorls; basal convexity; and finally in the shape of the aperture.

"*Helix* (*Mesodon?*) *dallii* suggests an ancestral form from which have proceeded such living representatives as are known by the names of *Helix columbianus*, *H. devia*, and varieties *H. germana*, etc. Of these well-known forms the first, *H. columbianus*, dominates through the greater portion of its geographical domain. Its distribution is northerly to Lituya Bay, Alaska (Dall), where it is found on the forest-clad benches which extend from the base of the Mt. St. Elias Alps westerly to the Pacific Ocean, in latitude 59°. Southerly it extends to the region around Monterey Bay, California, (Hemphill), latitude 36°; and if *H. devia* variety, from Salmon Springs, Idaho (Hemphill), may be regarded as so nearly related to *H. columbianus* as to warrant its being placed as a variety of the latter, then the range of the species is eastward to the meridian of 116°. Individuals which unquestionably belong to *H. columbianus* have been collected at or near the Dalles of the Columbia River, near the 121st meridian. There is reason to believe that the southern boundary of its range may be placed still further south, even to the region bordering upon the Santa Barbara Channel, south of latitude 34°. (Museum No. 13401.)

"I have proposed for the specific name of this interesting form that of the eminent conchologist, Mr. W. H. Dall."

in the Eureka mining district, Nevada; and he has given to them the following names: *Ampullaria? powelli*, *Physa prisca*, and *Zaptychius carbonaria*.[12] These three species were published with figures in Science, Vol. II, p. 808 (1883), and also in Monograph VIII of the United States Geological Survey, pp. 261–263 (1885).

These shells are especially interesting on account of their great geological age and the evidence which they present of the great antiquity of two of the common fresh-water genera among living mollusks. Pulmonate gasteropods belonging to the Geophila have long been known in Carboniferous strata, but these are the first fresh-water gasteropods that have yet been found in North American strata of that age.

There seems to be no room for doubt that the shell which Mr. Walcott refers to *Physa* is a typical species of that genus, nor that the animal which formed it was in all essential respects like its living congeners. The form which he refers with doubt to *Ampullaria* apparently belongs to that genus; and its association with *Physa* favors this view of its generic character. *Zaptychius* is a new genus proposed by Mr. Walcott, which appears to belong to the Auriculidæ. It is therefore suggestive of a more or less brackish condition of the water in, or near which it lived.

Under the head of "Spurious and Doubtful Species," as treated in the "Review," mention should have been made of an Alaskan shell which Eichwald referred to the *Unio martini* of d'Orbigny. The shell in question was one of the collection which was made in Alaska by Peter Doroschin, and which was published by Dr. E. von Eichwald in a work entitled "Bemerkungen ueber der Halbinsel Mangischlak und die Aleutischen Inseln," page 168, Plate XVI, Figures 28 and 29. The specimen which he figures and describes, and which appears to have been the only one of the kind found by Doroschin, is less than a centimeter long, and is only a natural cast of the interior of the shell. Its generic identity could not therefore have been determined with certainty; and even if it had been found associated with a fresh-water fauna, it would have been impossible for any one to say with certainty that it belongs to the genus *Unio*, much less to say to what species it belongs. Having been found associated with *Ammonites* it is without doubt a marine shell and therefore not a *Unio*, and mention is made of it here only because it was referred by Eichwald to that fresh water genus.

CORRECTIONS.

On page 459 (53) of the "Review," I have said: "Although *Cerithidea* is a well known living genus of the Old World, this species at present stands alone, or without near known allies, either living or fossil, among North American mollusca, if its generic relations are correctly understood, as stated above." That the shell referred to (*Cerithidea nebrascensis* Meek & Hayden) does thus stand alone as a distinct type, I still think is true; but the implied statement that there are no living species of *Cerithidea* in North America is an error. Several typical species of that genus are known to exist on both coasts of the southern part of North America. None of those species, however, nor any other North American forms known to me, either fossil or living, are of the type of the fossil form referred to. Meek & Hayden placed it with doubt in the subgenus *Pirenella*, but it seems to be more like a true *Cerithium*.

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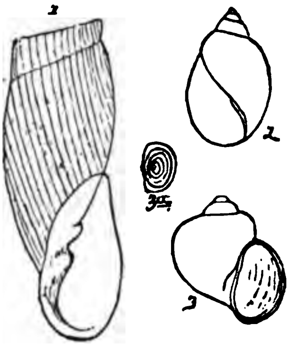
[12] See figures on next page.

Again, on page 423 (17) of the "Review" I have said that the genus *Dreissena* van Beneden "is not known to be represented in North America by a single species, either living or fossil." At that time I regarded the *D. leucopheata* of Conrad, which is found along our Atlantic coast, together with a similar if not identical form found in Florida, as belonging to the genus *Modiola*. The animal of these forms has not yet been studied, but conchologists now generally accept them as species of *Dreissena*.

On page 469 (63, of the "Review," eighteenth line from the top, for "*Campeloma multistriata*" read *Campeloma multilineata*.



1. Zaptychius carbonaria.
2. Physa prisca.
3. Ampullaria? powelli.
3*a*. Operculum of the same.

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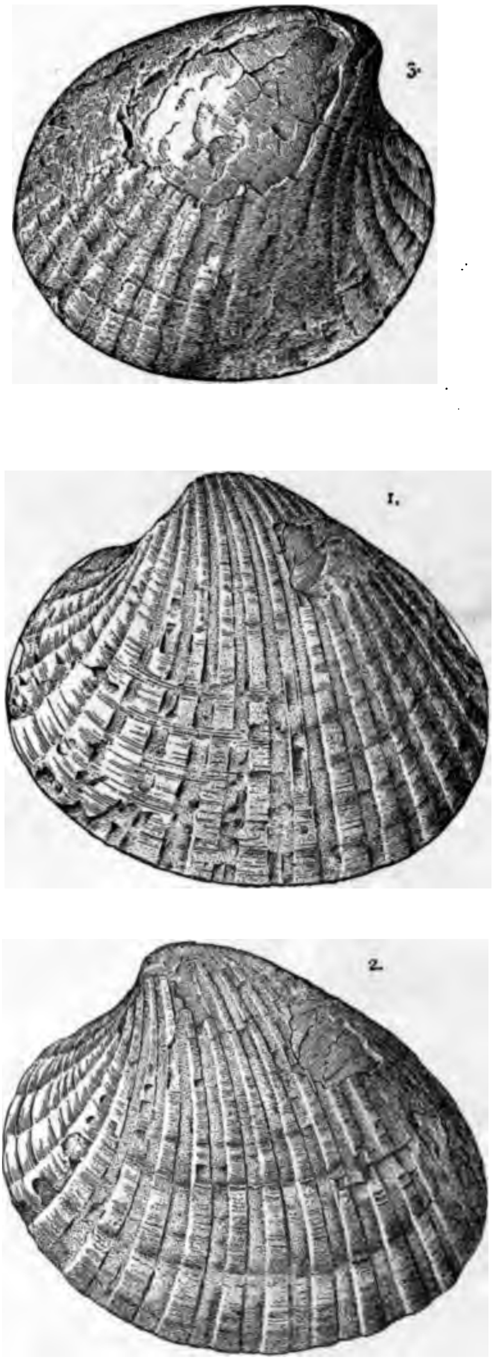
EXPLANATION OF PLATES.

PLATE I.

CARDITA PLANICOSTA.

Fig. 1. Lateral view of a left valve.
Fig. 2. Similar view of another left valve.
Fig. 3. Similar view of a right valve.



CARDITA PLANICOSTA.

PLATE II.

UNIO CONDONI.

Fig. 1. Lateral view of a right valve and part of a left valve.
Fig. 2. Right side view of an imperfect example, showing eroded beak.
Fig. 3. Vertical view of Fig. 2. All of natural size.

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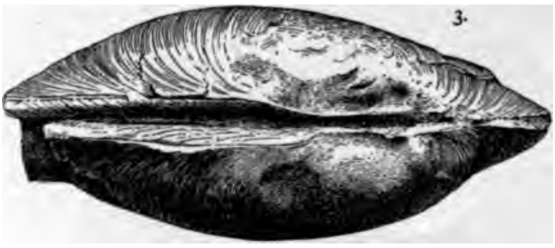

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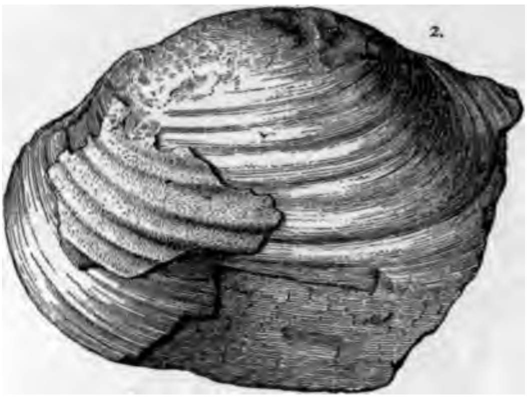

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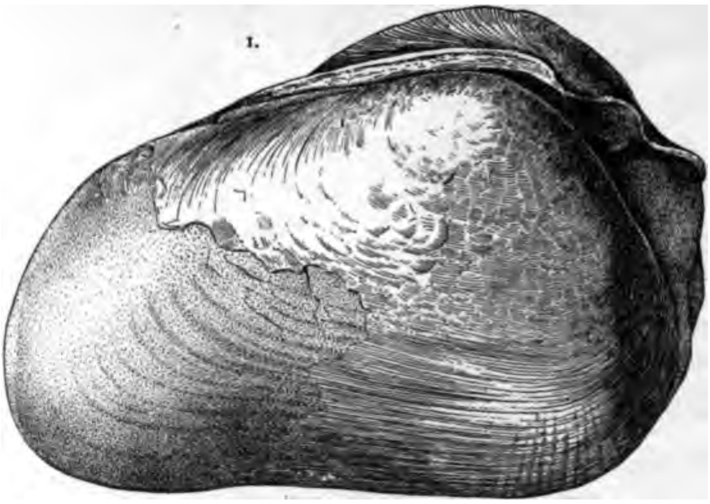


1.

UNIO CONDONI.

PLATE III.

HELIX (AGLAIA) FIDELIS.

Figs. 1, 2, and 3. Lateral, vertical, and basal views of the same individual.

HELIX (MESODON?) DALLII.

Figs. 4, 5, and 6. Lateral, vertical, and basal view of the same individual.

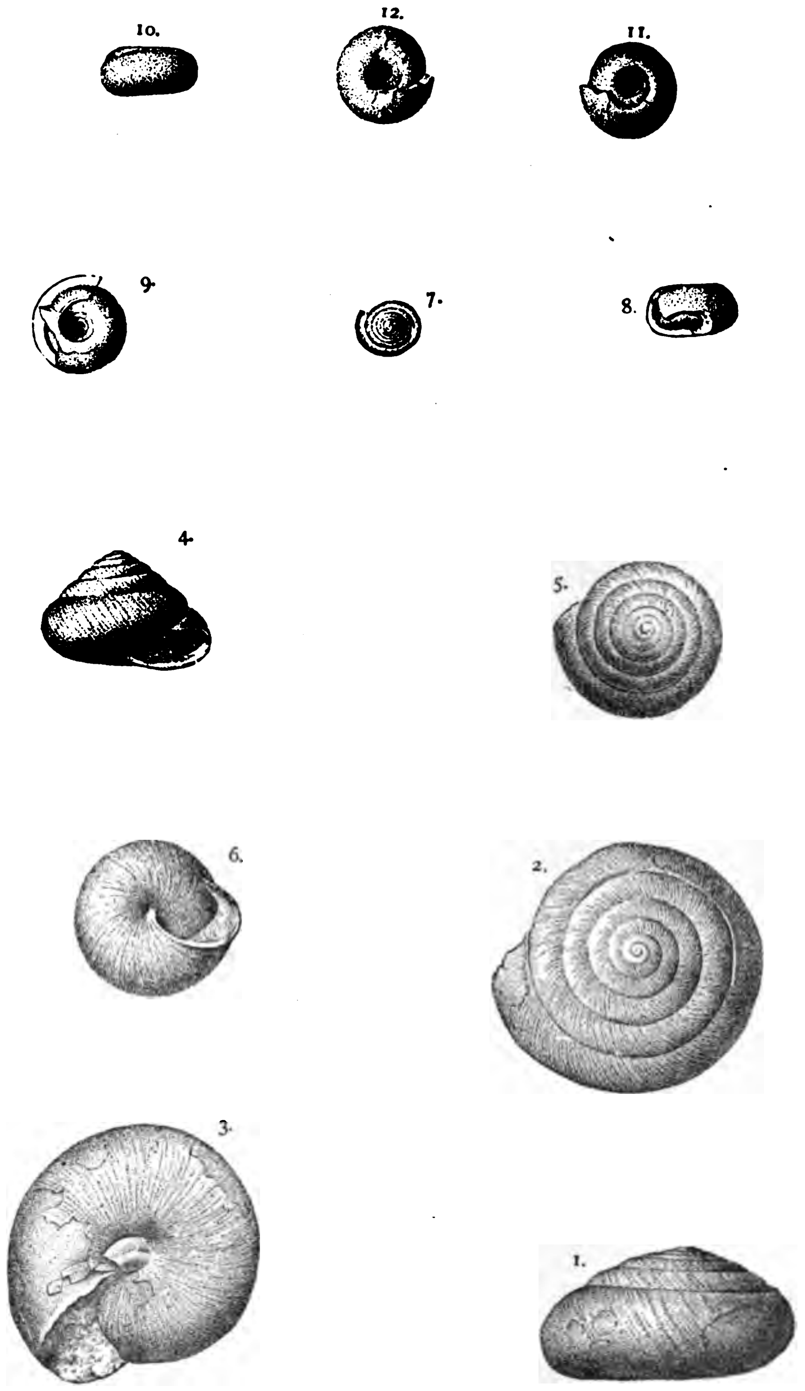
HELIX (PATULA) PERSPECTIVE.

Fig. 7. Vertical view of an imperfect example.

GONOSTOMA YATESII.

Figs. 8 and 9. Lateral and vertical views of an imperfect example.

Figs. 10, 11, and 12. Lateral, vertical, and basal views of another imperfect example.



HELICIDÆ.

DEPARTMENT OF THE INTERIOR

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GEOLOGICAL SURVE

No. 19

NOTES ON THE STRATIGRAPHY OF CALIFORNIA

WASHINGTON
GOVERNMENT PRINTING OFFICE
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DEPARTMENT OF THE INTERIOR

BULLETIN

OF THE

UNITED STATES

GEOLOGICAL SURVEY

No. 19

WASHINGTON
GOVERNMENT PRINTING OFFICE
1885

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UNITED STATES GEOLOGICAL SURVEY.
J. W. POWELL DIRECTOR

NOTES

ON THE

STRATIGRAPHY OF CALIFORNIA

BY

GEORGE F. BECKER

WASHINGTON
GOVERNMENT PRINTING OFFICE
1885

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NOTES ON THE STRATIGRAPHY OF CALIFORNIA.

BY GEORGE F. BECKER.

INTRODUCTORY.—A complete examination of the Coast Ranges of California can hardly be undertaken by the Geological Survey for some years to come, consistently with the plans at present formed. The detailed study of certain small areas in these ranges, however, raised a number of questions as to the age and stratigraphical relations of the various series of beds, which it seemed necessary to answer as well as circumstances permitted. Having reached certain conclusions, for the most part on structural grounds, it became indispensable for me to obtain the co-operation of an expert paleontologist. At my solicitation, and with the approval of the director, Dr. C. A. White consented to visit the field with me. He passed several months of the summer of 1884 in studying my collections and the occurrence of fossils in place with reference to the points at issue. His results appear in Bulletin No. 15, that and this being complementary to one another. I had the great satisfaction of finding that Dr. White was led from a purely paleontological position to conclusions entirely accordant with those at which I had already arrived on structural grounds. His long experience as a general geologist also made his agreement with me as to the structural indications a welcome confirmation of my opinions. These studies, in conjunction with many observations made by earlier workers on the Pacific Coast, particularly those of the State Geological Survey of California, under Prof. J. D. Whitney, have led to some seemingly well established general conclusions of interest. The more purely geological results will be presented in the following pages, in the imperfect form in which alone it will be possible to give them until an immense amount of additional work shall have been done.

METAMORPHISM IN THE COAST RANGES.—Throughout the Coast Ranges of California there occur large irregular areas of rocks in the condition ordinarily regarded as metamorphic. They are characterized lithologically by the presence of serpentine (perhaps accompanied by some other magnesian minerals) or silica, or both. Of the secondary nature of the silicification there can be no doubt, since the quartz and opal occur mainly in the form of veins and stringers, for the most part occupying tiny cracks in the rock. The serpentine was also regarded as an alteration-product by Professor Whitney and his assistants, and with this opinion I am compelled to agree, after a careful study of the phenomena, both structural and microscopic, the details of which will be published on another occasion. Where the stratification of the metamorphic rocks is not obliterated, they are seen to be greatly disturbed, having been sometimes broken up into a chaotic mass of fragments, since cemented by silica or serpentine, and sometimes thrown into sharp plications. In the latter class of cases it is often clear that plication has not been effected by flexure, but by innumerable fractures, the resulting fragments often averaging less than one-quarter inch cube. These particles were retained in approximately their original position by mutual pressure, and have been recemented by silica. The most striking instances of this character are seen among thin-bedded rocks, either sandstones or sandy shales, and such are remarkably frequent in this series; indeed they might be said to be characteristic of it, though occasionally met with in formations which appear to be later than the most important era of metamorphism.[1]

Besides the rocks referred to above, the Coast Ranges include others which have been subjected to more or less complete alteration. Thus along the shore of Carmelo Bay, Miocene schists have been locally changed to a cindery mass, as if by the action of heat, but these rocks bear no resemblance to the serpentinized and silicified material just described. More or less complete induration is common even in the most recent rocks of the coast, and oxidation and impregnations with calcite and gypsum occur abundantly in rocks of all ages. In the present paper, however, the term metamorphism, unless specially qualified, must be understood to refer to serpentinization, silification, and associated changes.

AGE OF THE METAMORPHIC ROCKS OF THE COAST RANGES.—Rocks of the metamorphic series often pass over into unaltered beds under such circumstances as to preclude a doubt that they are of the same age; but unfortunately the unchanged strata seldom contain determinable fossils, and only a small number of occurrences are known in which the age can be satisfactorily established by direct evidence. In addition to these cases, however, there is a considerable amount of tolerably satisfactory indirect evidence available, when all the circumstances are taken into consideration. The neighborhood of Knoxville, Napa County, affords an excellent opportunity for the study of the metamorphic rocks. This region has also been mapped and examined in detail as a portion of a series of studies which, with abundant illustrations, will appear hereafter. A section across the north fork of Davis Creek, a little north of the Reed mine, a short distance from Knoxville, shows that the ravine occupies an eroded anticlinal of which the western portion is highly metamorphic, while the eastern consists in part of highly fossiliferous strata, containing *Aucella* of two varieties, with other molluscan remains. A map of the region shows that the strike of the unaltered strata throughout is tolerably constant, but that areas of metamorphic and unaltered rocks, the latter nearly all containing a few fossils, are interspersed in the most irregular manner. While the passage from metamorphosed to fresh rock is usually rather sudden, there are also clear cases of transition. The whole structure and the stratigraphical relations are such as to preclude every supposition except that the metamorphic rock is an alteration product of the same beds which contain *Aucella* and the accompanying fossils. These fossils, and these only, occur over a strip of country several miles in length, in which Knoxville is the only town. Dr. White and I have therefore agreed to call these characteristic beds the Knoxville group. Their age, as may be seen from Dr. White's bulletin, is near the limits of the Jurassic and the Cretaceous, and it is not quite certain to which they belong, if indeed they are not intermediate or transitional.

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[1] The peculiarity of these thin-bedded, plicated, metamorphic rocks was observed and frequently referred to by Professor Whitney.

Close to the Manzanita gold and quicksilver mine on Sulphur Creek, in Colusa County, the metamorphic rocks contain impressions of *Aucella Piochii*, and close by are beds of limestone full of *Rhynconella Whitneyi*.[2] The metamorphic rocks of this region are serpentinized and silicified, and the thin-bedded strata show the characteristic contortions accompanied by a fine network of veins of silica. At Mount Diablo, too, there is abundant proof of the Knoxville age of the metamorphic rock. Professor Whitney, writing before Mr. W. M. Gabb had made his final divisions of the California Cretaceous, mentions the occurrences at Mount Diablo as conclusive of the Cretaceous age of the metamorphic rocks, but without enumerating the associated fossils. From an examination of the fossil localities in Mr. Gabb's work, however, it appears certain that these were *Aucella*, etc. An examination which Dr. White and I undertook for the purpose shows that in Bagley Creek, about a mile from the summit, *Aucella* occurs abundantly close to the edge of metamorphosed strata; indeed, in partially metamorphosed strata conformable with those extremely altered, and in structural relations to them, which clearly indicate the same age. My assistant, Mr. H. W. Turner, subsequently found a series of beds, some of which had escaped action and contained *Aucella*, though inclosed on both sides by highly metamorphic strata. Mr. Gabb also mentions[3] an *Aucella* locality near the New Almaden mine which I have not thus far been able to identify.

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[2] These specimens were determined by direct comparison with specimens in the collection of the State survey. The figure given in Pal. Cal., Vol. II, Plate XXXIV, is incorrect in important particulars.

[3] Pal. Cal., Vol. II, p. 247.

So far as is known, that part of the country consists of metamorphic rocks overlain by Miocene strata, and there can be little doubt that the *Aucella* beds belong to the metamorphic series. Alcatraz Island, close to San Francisco, consists of metamorphic sandstone and shales not distinguishable from those of San Francisco or of Mount Diablo. Here Major Elliott discovered an *Inoceramus*, considered by Mr. Gabb and Dr. White as establishing the Cretaceous age of these rocks, though indecisive of the portion of this formation to which they should be referred. The above comprise all the instances known in which the age of the silicified and serpentinized metamorphic rocks is directly determinable by paleontological evidence.

Of other cases of alteration of rocks known not to belong to the Knoxville beds I have already mentioned the very remarkable but utterly different change in the Miocene strata near Monterey. In the Arroyo de la Penitencia above Alum Rock, near San José, there is also an area of altered Miocene sandstones referred to by Professor Whitney.[4] The rock here is much indurated and is full of veins of calcite. No objection can be made to its description as metamorphic by Professor Whitney, but it is not serpentinized and silicified, and does not partake of the characteristics so strongly marked in the highly metamorphosed rocks of the Knoxville group. On the other hand, there are plenty of rocks of this group no more altered than the Miocene of the Arroyo de la Penitencia and some areas still less modified. The Tertiary of the Arroyo has been subjected to influences seemingly identical with those which have affected portions of the Knoxville beds, but not to those which have produced in the older strata the characteristic serpentinization and silification. Professor Whitney also refers[5] twice to altered beds in the San Francisquito Pass, which, indeed is to the south of the Coast Ranges as usually defined. In the first reference he states that "this belt of metamorphic is referred by us to the Cretaceous formation, from general analogy rather than from any direct evidence of fossils." In the second reference they are mentioned as "Miocene rocks turned upon edge and so much metamorphosed as to be converted into mica slate." No statement of the means of determination of the age of these beds accompanies this remark, which, however, occurs in a brief summary of the geology of the Coast Ranges. Whatever the evidence may be upon which the change of reference was made, it can have little bearing upon the age of the metamorphics in the central Coast Ranges, nor is serpentinization referred to as forming a part of the phenomena.

So far as is known, therefore, no beds in the Coast Ranges of California younger than the Knoxville group have experienced the peculiar magnesian and silicious metamorphism so characteristic of these ranges. No fossils antedating the Knoxville period have anywhere been discovered in the Coast Ranges. For the most part it would seem that rocks indistinguishable in habitus from the Knoxville group rest directly upon the granite. In the Gavilan Range, however, an extremely crystalline limestone is the lowest sedimentary formation.[6] It is so highly metamorphosed where thus far seen as to offer no hope of fossils, and its general appearance is such as to suggest a far greater age than the Jurassic. Nothing of the kind is known to exist between this point and Clear Lake. A portion, at least, of the characteristic metamorphism of the Coast Ranges took place before the beginning of the Chico period. Metamorphic pebbles are common in the Chico conglomerates, but these are usually wholly silicious. This is in no way inconsistent with their having been derived from areas of metamorphosed Knoxville beds, for serpentine is easily abraded and easily decomposed, so that it readily escapes redeposition. These pebbles might also, however, have been derived from some earlier metamorphic area not now exposed. But in the Wallala[7] beds, a series extending along the coast from near Fort Ross at least to Wallala, and which Dr. White regards as probably prior to the Chico, serpentine pebbles from the adjoining metamorphic area are tolerably abundant. This area is a large one and no Knoxville fossils have been found as yet near Wallala, but the metamorphic is continuous with that of Colusa and Napa Counties, where we know that the magnesian metamorphism involved the Knoxville beds. These pebbles, then, are probably of Knoxville age. New Idria lies at the southern extremity of the Mount Diablo range, which takes its name from its most northerly peak. The range is essentially a metamorphic ridge flanked by inclined strata not altered. The metamorphic axis can be followed almost continuously, and perhaps quite so, but while at the northern end the metamorphic rocks are certainly of Knoxville age, at the southern end the externally indistinguishable material contains, so far as known, only a few indeterminable plant remains. It appears to me almost beyond reasonable doubt that the metamorphic of New Idria includes Knoxville beds.

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[4] Geol. Cal., Vol. I, p. 51.

[5] Geol. Cal., Vol. I, p. 196. Aur. Grav., p. 19.

Similarity of lithological and physical character may, I think, be given too much weight in geological diagnosis. I cannot conceive, for example, that any degree of similarity between the rocks of California and those of Switzerland should properly be considered as even tending to prove the age of either. I go farther, and refuse to regard the metamorphism of the rocks of Butte County as necessarily contemporaneous with that of the strata of Napa County in spite of external similarity. On the other hand, within properly limited areas, observations show that the same fauna is associated with similar rocks; while if it were impracticable to draw any conclusions as to age, except where the rock is fossiliferous, or where absolute continuity with fossiliferous localities, uninterrupted by faults, could be proved, geological mapping would be impossible. In California great use can be made of resemblances. Thus the Téjon strata of New Idria are mostly heavy bedded sandstones of a peculiarly light color, which there distinguishes them from the tawny Chico sandstones. Both are fossiliferous there as also near Mount Diablo, where, at a distance of 125 miles from New Idria, they preserve the same external characteristics. Similarly, the Knoxville beds of Knoxville and Mount Diablo are externally indistinguishable and, in their typical development, even when unaltered, very different from most of the later rocks.

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[6] Cf. Dr. Antisell's paper in Pacific Railroad Survey, Vol. VII.

[7] This name is variously spelled Gualala, Guadala, Walhalla and Wallala. The last is the spelling adopted by the Coast and Geodetic Survey after careful scrutiny and consideration. [illegible]

[illegible]

Excepting the peculiar limestones of the Gavilan Range, there is no occurrence known in the Coast Ranges which suggests the presence of beds older than the Knoxville. Such may nevertheless be included in the metamorphic series, and may have undergone upheaval and metamorphism at the same date. There is also a possibility that older rocks not only exist, but were metamorphosed before the deposition of the Knoxville, so that the metamorphic areas in contact with the Wallala beds on the coast and with the Chico strata at New Idria may conceivably be earlier than the Knoxville. Even this supposition, which, in the absence of any evidence tending to it, seems rather far-fetched, would have no effect on the conclusions drawn in this paper, unless it could be maintained, not only that such was the case, but also that the violent upheaval and metamorphism which followed the Knoxville left the supposed older areas undisturbed. This would conflict with all analogy.

It is, perhaps, worth while to note that as a rule the character of the topography of the areas occupied by Shasta rocks differs widely from that of regions in which only the more recent beds are laid bare. In the metamorphic areas the valleys usually occupy anticlinals, though the erosion appears to have been partially controlled by the extent of the metamorphism.[8] Such surfaces necessarily indicate extremely prolonged exposure. On the other hand, where the surface is occupied by rocks of the Chico or later groups, erosion has often approximately followed the bedding.

The foregoing facts and the necessary inferences from them appear to justify the statement that the silicified and serpentinized metamorphic rocks of the Coast Ranges include a portion of the Knoxville beds, and do not include any portion of the Chico or of the Wallala series, while if there were pre-Knoxville rocks within the metamorphic areas they must have undergone at least a fresh disturbance at the time when the Knoxville beds were broken up and metamorphosed.

NONCONFORMITY BETWEEN THE KNOXVILLE BEDS AND THE CHICO.—Had the proof of this nonconformity been a simple matter, it could not have escaped attention of some one of the several able geologists who have done more or less work in the Coast Ranges. The difficulty is in part due to the rarity of fossils in the older groups over a great portion of the area in question, which often leaves the observer without absolute proof of the age of the rocks about him; but the main obstacle arises from the complexity of structure. Few geological phenomena are more striking than a nonconformity where the overlying strata are nearly horizontal, the underlying rocks greatly inclined and the exposure tolerable. This combination is rare in the Coast Ranges, and no such case is known where the Shasta and Chico beds meet. The post-Miocene uplift traced by Professor Whitney has folded, faulted, and broken the later Cretaceous and the Tertiary rocks as well as the earlier strata upon which they were unconformably deposited, so that it is usually far from easy to make out the effects ascribable to the earlier and later disturbances respectively, and still more difficult to prove that no explanation except that of a nonconformity before the Chico will account for the facts. I believe that the structural evidence to be presented amounts to a demonstration of this nonconformity, but even after having delayed publication for a considerable time in order to secure more data, the proof, though convincing, is less abundant than I could wish it. The paleontological argument for this nonconformity is a very strong one, as will be seen from Dr. White's paper, but I had detected the gap before he joined me and while in ignorance that an hiatus existed in the succession of organic forms. The evidence will, therefore, be presented here chiefly from a purely structural standpoint.

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[8] Cf. Dana's Manual, p. 750.

In the neighborhood of the New Idria mine the metamorphic rocks have been greatly disturbed, while the Chico strata though tilted at a high angle are remarkably regular. Owing to the steepness of the contact, however, I was unable to find any exposures showing both series together from which thoroughly satisfactory inferences could be drawn as to the relations of the underlying and overlying rocks. I therefore resorted to a study of the exposures of each separately, for which the region offers unusual facilities. It was found possible to follow single strata of the Chico uninterruptedly for a large part of a mile, and in favorable cases to recover the croppings with substantial certainty after passing intervals covered with detritus, by the aid of lithological peculiarities combined with topographical indications and the strikes observed at the exposures.[9] The contact with the metamorphic rocks was also laid down and a great number of dips were observed in the metamorphic area. In order to eliminate the irregularities due to the varied topography of the lines of croppings, and the contact as laid down on the map, each line of croppings was reduced to its intersection with a plane of the mean altitude of these croppings, following the indication of the local dips. The results showed that the Chico strata are parallel in strike and thrown into extremely gentle undulations, while the metamorphic area is a mere shattered mass. The contact has approximately the same general direction as the Chico beds, but does not entirely coincide with their strike. It is a rough line, but not rougher than one which would represent the vertical section of an ordinary sea-bottom near the coast. The dip of the Chico strata decreases as the distance from the contact increases.

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[9] This would have been excessively difficult, if not impossible, but for the aid afforded by an almost ideally good contour map on a scale of 800 feet to the inch prepared for me by Mr. J. D. Hoffmann.

This structure either represents a nonconformity or else the metamorphism and accompanying disturbances occurred after the deposition of the Chico beds but ended sharply at a certain line. It might at first sight seem impossible that an area several miles in width should be crumpled, broken quite as thoroughly as a representative area of the Archæan along the eastern coast, and further for the most part converted into serpentine and chert, but that both mechanical and chemical action should cease abruptly at a given line. Nevertheless instances of which the above might pass for a description actually occur and are perhaps more frequent in the Coast Ranges than elsewhere. All geologists who have visited this region are aware of the very irregular distribution of the metamorphic areas and it has already been pointed out that, for example at Knoxville and at Mount Diablo, the metamorphic passes over into unaltered or very slightly altered Knoxville beds suddenly, though under circumstances which preclude the supposition that the adjoining areas represent different formations. There are, however, significant differences between these occurrences and the conditions at New Idria. The limits of metamorphism in areas consisting of Knoxville beds, however sharp they may be, are exceedingly irregular, the outline being substantially independent of stratification, cutting strata more often than following them, and presenting all sorts of convolutions. There are almost invariably also outlying areas of metamorphic rock and included masses of unaltered rock. Furthermore at least here and there are distinct transitions between unaltered and metamorphic rock. At New Idria, on the other hand, a section of the contact normal to the surface extends over at least several miles (as far as it was followed) in a tolerably straight line. There are no outlying patches of metamorphic rocks; the included masses of comparatively unaltered rock seem wholly different from the Chico strata above them and, though there is a considerable alteration of a portion of the overlying mass, this alteration is not of the same character as the magnesian and silicious metamorphism of the underlying rock; nor could I find any distinct case of transition. Finally, in the Chico conglomerates a part of the pebbles seem entirely to resemble the silicified or jaspery portions of the present metamorphic area while a few appear both macroscopically and microscopically identical with the serpentinized rocks of Knoxville age.

Some further evidence of the relation of the two series was found a few miles to the southeast of New Idria, where a branch of Cantua Creek cuts through a portion of the range. Here the heavy-bedded, tawny Chico sandstones, lying at an angle of about 45°, cap the hills which are intersected by the brook, while in the bed of the stream the thin-bedded metamorphic strata stand vertically. No actual contact, however, could be found, the interval being covered with detritus.

There seems no reasonable explanation of the structure at and near New Idria, except by the existence of a non-conformity. Though the evidence may seem less satisfactory than that which would be presented by an ideal exposure, it is derived from the correlation of the structural evidence along the contact for miles, and in this respect is superior to any but the very best local exposures of unconformable contacts; for every geologist must have observed cases where unconformable exposures were closely simulated by local faults. Could it be proved that the underlying mass is of greater age than the Knoxville the evidence would nevertheless indicate a non-conformity between the Chico and the Knoxville, unless it could be shown that the convulsion which has so marvelously crushed the Knoxville beds, at least from Clear Lake to the neighborhood of New Almaden, was unfelt at New Idria, while the comparatively gentle post-Miocene upheaval certainly extended throughout the Coast Ranges of California and Oregon.

Mount Diablo and the surrounding country consist of a core of metamorphic rock inclosed nearly or quite quaquaversally by rock of Chico and Tertiary age. The core is highly contorted, and for the most part is in an extremely metamorphosed condition, though here and there it is comparatively fresh, and in some cases contains *Aucella* and associated fossils. The overlying Chico, Téjon, and Miocene strata are tilted, but otherwise comparatively undisturbed. Over wide areas these three series seem to be perfectly conformable, nor is there any case known on the Pacific coast where there seems any ground for suspecting a non-conformity within these limits. Mr. H. W. Turner, my assistant, spent several days in this region, collecting fossils from various beds and searching for some exposure in which the relations of the Knoxville beds and the Chico could be well made out. The result was negative, no exposure being detected from which a non-conformity could be established beyond a question. On the other hand, the structure is much more easily accounted for by supposing a non-conformity to exist than by assuming conformity. The upturned edges of the more recent strata form long, smooth curves enveloping the plicated and metamorphosed core, and nowhere was there any metamorphism in the strata identified as Chico. The pebbles of the Chico conglomerates were metamorphic, but entirely silicious, and neither distinctly the same as the core of the mountain nor essentially different.

From about a mile south of Fort Ross northward for an unknown distance the sea-coast of California is formed by a terrace separated from the beach by cliffs.[10] The rock exposed on these cliffs and at croppings on the terrace is composed of soft tawny sandstones, like those of the Chico, dark shales, and coarse conglomerates. The sandstone predominates. About a mile north of Wallala several fossils were found, and careful search at many points to the southward disclosed a few more from the same beds. These Dr. White regards as probably older than the Chico, but younger than the Knoxville group. At the chief fossil locality, near Wallala, the shells were found in part in sandstones and in part in the matrix of a conglomerate the pebbles of which are serpentine and other metamorphic rocks (exactly similar to those of typical metamorphic areas of Knoxville and Mount Diablo) and granite. The metamorphic pebbles are considered as valid evidence that the metamorphism and accompanying disturbances took place before these Wallala beds were deposited.

At the southern extremity of this terrace, below Fort Ross, there is a sharp contact between the Wallala beds and the metamorphic serpentinized rock which extends from this point to below the Russian River, if not to the Golden Gate. Passing back into the hills, the Wallala beds are found capping the first range of elevations opposite portions of the shore which are composed of the metamorphic rocks. I believe no one could examine this locality without being convinced that the Wallala beds rest unconformably upon the metamorphic, nor could any one pass inland from the mouth of the Russian River to Knoxville without feeling sure that the metamorphic is uniform in character and substantially continuous, though occasionally masked by eruptive rocks and possibly by a few patches of unaltered strata.

There is furthermore much indirect structural evidence that a nonconformity must exist between the Knoxville beds and the Chico. The exposures at Mount Diablo show that there, at least, no deposits were formed between the Knoxville and the Chico. Were the fauna of the Wallala beds more decisive as to age, it might therefore at once be maintained that during the Wallala period the Knoxville beds of Mount Diablo must have been above water. But this argument is not necessary. Upon the Chico lies the Téjon (I omit the Martinez[11] as a mere subdivision), and next follows the Miocene. The stratigraphical relations, as well as organic forms, show a continuous sedimentation and a continuity of life between the Chico and Téjon. Between the Téjon and Miocene there is nowhere any suggestion of a non-conformity.[12] Near New Idria and at Mount Diablo, for example, the Miocene seems as strictly conformable with the Téjon as this with the Chico. So, too, along the flank of the Sierra Nevada, both Chico and Miocene remain almost perfectly horizontal. There is, in fact, evidence that the country was sinking at the period of time which separates the two eras. Had there been a great upheaval, accompanied by intense metamorphism, between the Téjon and the Miocene, it seems impossible not only that no trace of a non-conformity between these beds should have been detected, but also that no Chico or Téjon strata should have been found metamorphosed. But somewhere between the end of the Knoxville and the beginning of the Miocene there was a great upheaval, accompanied by silicious and magnesian metamorphism and followed by enormous erosion; for at many points the unaltered Miocene rests unconformably upon the metamorphic rocks. This I have observed on San Bartolo Creek and in the valley of the San Benito, to which the other is tributary. Professor Whitney found the Miocene resting unconformably upon the metamorphic between the Guadalupe Mine and Forbes's Mill, also near McCartysville,[13] as well as north of the Golden Gate;[14] for instance, near Tomales,[15] while, in speaking of the neighborhood of Suscol, he says[16] "it is probable that the most extensive disturbances of the Cretaceous, as also the larger portion of the metamorphic action upon it, had taken place before the Tertiary marine and volcanic beds were deposited."

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[10] This terrace appears to me beyond question a raised beach. A careful comparison of its topography with that of the beaches more or less exposed at low tide showed a correspondence in character seemingly perfect. Still better evidence was the discovery of rock in place on the terrace at two points separated by several miles, in which were unmistakable *Pholas* borings indistinguishable from those frequent at the present water-level. Some of them were filled with hardened earth which had preserved their interior surfaces perfectly smooth. One locality was by estimation about 100 feet above tide water, the other more than double this elevation. As is well known, there have been differences of opinion as to the character of the terraces on the California coast.

[11] This name has crept into geological literature under the entirely incorrect form Martiñez.

There being nothing whatever to indicate any upheaval between the Téjon and the Miocene, this indirect evidence alone is sufficient to establish the fact of a non-conformity between the close of the Knoxville and the beginning of the Chico. Add to this the direct evidence at New Idria and Fort Ross, and to this again the paleontological evidence of an hiatus in the organic succession, probably amounting to the entire period represented by the sum of all the Cretaceous rocks of the country east of the Rocky Mountains, and it appears to me that the conclusion is irresistible. The precise time at which the Knoxville strata were upheaved and metamorphosed cannot be determined from any known facts. It must have been long before the first of the Wallala beds were deposited, and still longer before the opening of the Chico period. In the absence of any strata intermediate in age between the Knoxville and the Wallala beds it seems more probable that the upheaval took place soon after the close of the Knoxville period than at a later date or neither long before nor long after the Neocomian.

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[12] Professor Whitney (Aur. Grav., p. 26) writes: "The Miocene and the Cretaceous seem everywhere to be conformable with each other." The Cretaceous here referred to is, of course, the Téjon.

[13] Geol. Cal., 1, p. 69. [14] *Id.*, p. 79. [15] *Id.*, p. 83. [16] *Id.*, p. 103.

IDENTITY OF THE MARIPOSA AND KNOXVILLE BEDS.—The gold belt of California, as hitherto traced out by miners and geologists, is an area of peculiar form. From Mariposa County to Nevada City, in Nevada county, a distance of about 150 miles, the belt is a strip of country nearly parallel to the crest of the Sierra, and about 30 miles in width. To the northward of Nevada City it rapidly widens, becoming at the same time less well defined. To the north it is finally terminated by extensive lava fields, while towards the northwest the country gradually loses its auriferous character as the coast is approached. Within the gold-bearing region three fossiliferous areas are known to exist. From the McCloud River to Pence's Ranch extends a belt of highly metamorphic limestone containing Carboniferous fossils. At Genesee Valley the State survey found fossils regarded as Triassic. Both of these localities are far removed from the narrow strip of country lying along the foot-hills from Mariposa to Nevada, and which is often known as the gold belt proper. In this narrow portion of the auriferous area, though the rocks are for the most part highly metamorphosed, a number of fossils have been found belonging to *Aucella*, *Belemnites*, etc., which are discussed in Dr. White's paper. Meek first described these fossils[17] and ascribed them to the Jurassic chiefly on the ground that *Aucella* "is, so far as is known, entirely confined to the Jurassic rocks."

Previous to the discovery of fossils on the Mariposa estate in the series which I shall call the Mariposa beds, Professor Whitney and his associates had collected in the Coast Ranges *Belemnites*, a shell determined as *Inoceramus Piochii*, and some others from the strata which I have entitled the Knoxville beds in this paper. Mr. Gabb described them as Cretaceous forms.[18] Some years after Mr. Meek had referred the Mariposa beds to the Jurassic, Mr. Gabb redescribed *Inoceramus Piochii* as *Aucella Piochii*,[19] a change of genus which I understand to be unquestionably correct. This correction would seem to have been of evident importance to the stratigraphy of the State, for through it the fauna of a large part of the known rocks supposed to belong to the Shasta group of the Cretaceous acquired the strongest resemblance to that of the Jurassic of Mariposa County. Indeed there seems scarcely room left for a distinction; if *Aucella* is distinctively Jurassic, the *Aucella*-bearing beds of the Coast Ranges must be members of that system, while if these *Aucella* beds are Cretaceous, *Aucella* is not a distinctively Jurassic genus even in the State of California, and Mr. Meek's principal reason for assigning the Mariposa beds to the Jurassic loses its validity.[20] Professor Whitney states that while the Mesozoic age of the

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[17] Geol. Cal., Vol. I, p. 477.

[18] Pal. Cal., Vol. I.

[19] Pal. Cal., Vol. II.

[20] This argument first suggested itself to me on a preliminary visit to Knoxville, two years since. From an inquiry on the subject addressed to Dr. White through one of our colleagues, eventually resulted his visit to this coast.

Mariposa beds is proved by their fossils the pre-Cretaceous age of these strata is demonstrated from their stratigraphical relations. Professor Whitney has indeed shown that Cretaceous strata rest unconformably[21] upon the upturned edges of the auriferous slates along the foot-hills of the Sierra at several points; but I find no record of any such bed so low as the Knoxville group.[22] All the fossils recorded in this position are Chico. This does not indeed preclude the possibility that the Mariposa beds are Jurassic, and the *Aucella* beds of the Coast Ranges Cretaceous, for the former might have been above water during the Shasta epoch. But were Cretaceous strata containing the so-called *Aucella Piochii* to be found resting in a nearly horizontal position upon the Mariposa beds, it would prove not only that the genus had persisted from Jurassic into Cretaceous times, but that in essentially the same locality the genus was represented immediately after a great and wide-spread upheaval by a species nearly or quite indistinguishable from one which had inhabited it prior to this convulsion and the attendant metamorphism. Zoölogists would probably think such a survival very strange if it could be proved, and very improbable unless the proof were ample.

On the other hand, if the Mariposa beds are considered as equivalent to the Knoxville beds of the Coast Ranges, the non-conformity between the Chico beds and those of Mariposa is the same which has been traced in the preceding pages as existing in the Coast Ranges. Dr. White, after examination of Meek's types and new and better specimens which we collected together, is unable to draw any specific distinction between the *Aucella* of the Mariposa beds, and that of the Knoxville beds. Were it otherwise the upheaval and metamorphism of the two series would still be referable to nearly the same period, and would be presumptively simultaneous.

The lithological resemblance of the rocks of the Mariposa estate to those of many portions of the metamorphic rocks of Knoxville age is very strong. There is a similar prevalence of thin-bedded strata which silicification and serpentinization are equally the predominant characteristics. Plication and fracture are less noticeable than in the Coast Ranges. One geologist has maintained that the fossiliferous rocks of this locality did not form an integral portion of the auriferous series. Neither Dr. White nor I was able to see any ground for this assertion. The fossiliferous rocks are metamorphic like the whole series; they have the same dip and strike; they are unquestionably auriferous, gold quartz veins occurring between fossil-bearing strata and not simply near them. In short we could see no means of separating the strata containing shells from the remainder of the immense thickness of similar and apparently conformable slates.

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[21] I am perfectly satisfied of the existence of this non-conformity, though the localities where the Chico beds have been found resting on the upturned edges of the auriferous slates are not near those in which Mesozoic fossils have been found in the older rocks. The Chico beds, where they occur along the foot-hills, have suffered little if at all from the post-Miocene uplift in the Coast Ranges and are nearly horizontal. The Mariposa beds are almost vertical.

[22] The shell from Tuscan Springs recorded, Geol. Cal., Vol. I, p. 207, as *Inoceramus Piochii*, is redetermined as a *Mytilus* in Pal. Cal., Vol. II, p. 191.

RELATION OF THE CASCADES TO THE SIERRA AND THE COAST RANGES OF CALIFORNIA.—It seemed highly desirable to institute some slight comparison between the California ranges and the Cascades. For this purpose we visited Roseburg, Oregon, and made several trips into the mountains. These are evidently underlain by granite, which forms a great portion of the stream pebbles, though we met none of this rock in place. In a great number of localities we found upturned, crumpled, silicified, and metamorphosed rocks exactly similar to those of Mount Diablo, but our search for *Aucella* was not rewarded. Upon the metamorphic rocks lie non-conformably somewhat tilted unaltered sandstones. These are certainly Miocene, for though we found no fossils ourselves, Dr. White examined extensive collections of Miocene shells in entirely similar rock collected by the Rev. Thomas Condon, who gave us full information as to their occurrence in precisely similar positions but somewhat north of Roseburg. Overlying the sandstones are large areas of volcanic rocks.[23]

In the section made by the Columbia River no metamorphic rock or granite appears, but at least the southern portion of the range has a foundation similar to that of the California ranges and probably due to the same upheaval. Dr. White points out that since Chico fossils occur to the east of the Cascades the site of the Cascades was at least in part covered by the western sea. This, however, is no objection to the proposition just made, for the interior of Oregon may have been a gulf similar to the present Gulf of California.

OTHER MESOZOIC BEDS.—The Horsetown beds, as it seems convenient to call the group which occurs near Cottonwood Creek, Shasta County, so far as known are confined to that locality, and their relation to the Knoxville series is unknown. The solution is very probably to be found in the eastern Coast Ranges in Tehama County, but this region is not known to have been geologically explored, and it probably will not be examined until a special study of the Coast Ranges as a whole is undertaken. The Horsetown beds are somewhat altered, but at the points visited by Dr. White and myself do not show the characteristic serpentinization and silicification of the metamorphosed Knoxville beds. It cannot by any means be asserted definitely, however, that they were not involved in the upheaval and metamorphism which took place after the Knoxville and before the Wallala period, because much of the Knoxville series is also little altered. On the other hand, the Horsetown beds rest unconformably upon the auriferous slates of that region, which are of unknown age, though apparently continuous with the Carboniferous of Pence's Ranch. Professor Whitney detected this nonconformity, though expressing the result in somewhat guarded terms.[24] The mining operations which have since been prosecuted have so exposed the rocks as to leave no room for any possible difference of opinion. The slates upon which the Horsetown beds lie are somewhat peculiar, and differ physically from those of the Mariposa beds, showing a very thin cleavage and a peculiar silver-gray luster. They give to the eye an impression of great geological age.

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[23] In an answer to an inquiry, Prof. Joseph Le Conte states that his remarks concerning the lower portion of the Cascade range in the Am. Jour. of Science, 3d s., Vol. VII, p. 177, were not from personal observation. He there suggested that the Cascades were a continuation of the Sierra.

Genesee Valley, in Plumas County, is the only known locality west of the crest of the Sierra at which Triassic fossils have been discovered. The fossiliferous rocks seem to belong to the Jura-Trias area of Nevada, and this reference is strengthened by topographical considerations, for though Genesee Valley lies to the westward of the highest crests of the Sierra in this latitude, it lies to the east of a lower range, which is more directly in the line of the general trend of the Sierra. This neighborhood is auriferous, but, as already explained, gold is disseminated through a very wide area north of Nevada County. Dr. White and I did not visit Genesee Valley, its geographical position being such as not to conflict with any of our conclusions.

PALEOZOIC ROCKS OF CALIFORNIA.—Dr. Trask long since showed that Carboniferous limestones make up the McCloud Range, which stretches along the McCloud River; and near Pence's Ranch, in Butte County, Professor Whitney's party found similar limestones also fossiliferous and clearly of the same age. Professor Whitney infers, on lithological grounds, that the more westerly limestones of the gold belt further south may also be Carboniferous.

Near Baird post-office, on the McCloud River, a considerable area of granite occurs about half a mile west of the fossiliferous limestone. The interval is occupied by extremely metamorphosed sandstones, in which my party failed to find any trace of fossils. These sandstones underlie the limestone, and are probably older, but there is no evidence to show whether they belong to the Carboniferous or to some preceding formation. To the northwest of Baird thin-bedded, plicated, metamorphic shales occur, bearing a strong resemblance to those of the Knoxville series in central California. Their structure and position are such as to suggest nonconformity with the Carboniferous, but, owing to the difficulties of traversing the country, we were unable to test this relation satisfactorily in a hasty visit to the neighborhood. Not a trace of a fossil could be found even in the least altered portions of the shales, and their age is therefore entirely uncertain, the lithological resemblance to the Knoxville group amounting to a mere suggestion at such a distance from well-ascertained members of that series.

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[24] Geol. of Cal., Vol. I, p. 321.

Near Pence's Ranch the shales are auriferous as well as certainly Carboniferous, at least in part. They also come in contact with Chico beds, which lie horizontally upon their upturned edges. The slates have a considerable similarity to those of the Mariposa group, and furthermore they are nearly vertical and strike in nearly the same direction as those of the gold belt proper. The question therefore at once arises whether their upheaval and metamorphism is ascribable to the same period as the uplift and alteration of the Mariposa and Knoxville beds. This is a subject which can be discussed only tentatively until a great amount of detailed work has been done in a somewhat unpromising field; but it is not too early to make some suggestions.

I think it may be asserted, as a result of all the geological work done from the Rocky Mountains to the Pacific, that there has been throughout geological time a definite tendency in the structural development of this area. The geologists of the fortieth parallel exploration showed that a fault began upon the west flank of the Wahsatch in the Archæan, the same fault which Mr. Gilbert has traced as still in progress. The last-named geologist has also detected a similar fracture on the east side of the lower portion of the Sierra. The eastern portion of the Great Basin was lifted above the surface of the ocean after the close of the Carboniferous, the western portion of the same area followed before the Cretaceous, and at one or both of these epochs the country was laterally compressed, an action no doubt closely connected with the progress of the great faults. About the time of the Neocomian, California experienced an east and west compression, and again following the Miocene was an uplift throwing the horizontal strata of the coast into north and south folds. From the Wahsatch to the Pacific Coast there thus appears to have been a recurrent, if not a constant tendency to lateral compression, in substantially one and the same direction. Now Dr. White points out that an extraordinary difference has existed between the marine fauna of the Pacific Coast and that of the waters east of the Sierra from a time prior to the Cretaceous onward, and hence that a land barrier must throughout have occupied substantially the position of the Sierra Nevada, which must therefore have experienced repeated upheavals to compensate for constant erosion. There are also said to be some paleontological grounds for supposing at least a partial separation of these areas during the Carboniferous. This supposition is in entire accord not only with the structural analogies of the region but with the detailed observations of Mr. Clarence King[25] and his colleagues, who were led to infer the existence of a continental-area during the Paleozoic west of long. 117°30′, lat. 40°. Such a range as the Sierra, though partaking in the general compression and movement of the whole country, must offer a tremendous resistance, and at any one of the active periods during which the physical conditions permitted contortion of strata along the western flank of the Sierra, these must have been driven against the barrier until they could yield no more. Thus if a pile of cloths were compressed from their edges (as in Hall's famous experiment) with enormous energy, they would be forced into plications so sharp that the dip at any point would be nearly vertical. It seems to follow that at different upheavals, some of them perhaps as yet untraced, strata to the west of the great Sierra may have been driven into the nearly vertical position of the gold slates and their original stratigraphical relations completely obscured. I do not consider it certain, therefore, or even probable that the Carboniferous slates near Pence's Ranch first assumed their present position subsequently to the Knoxville period. It may be that they have stood nearly as now ever since the Carboniferous of Utah was raised above water, while the slates of Horsetown, of the age of which nothing is known, so far as I can see, may possibly owe their vertical dip to still earlier convulsions.

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[25] Systematic Geology, p. 534.

The Carboniferous slates of Pence's Ranch are serpentinoid, and, though distinctions between them and the metamorphosed Knoxville beds might perhaps be drawn, they are very similar. But just as it seems to me that successive upheavals may have produced similar results, I think the association of a certain uplift with a particular series of chemical changes in an argument for the supposition that analogous dynamical conditions might lead to molecular changes of the same kind. It seems therefore not at all impossible that both upheaval and metamorphism at Pence's Ranch were in the main earlier phenomena than those traced in the Coast Ranges. If so, their effect must have been felt throughout a great portion of California, though the results may have long since been obliterated. On the other hand, the post-Knoxville disturbance must have been felt at Pence's Ranch, though its effects may have been trifling as compared with those of earlier convulsions.

THE COAST RANGES MEMBERS OF THE WESTERN CORDILLERA SYSTEM.—As has already been stated, I am unable to see any reason for dissenting from Professor Whitney's opinion that the fossiliferous beds of Mariposa form an integral portion of the modern Sierra Nevada Range. It seems simply impossible that they should have assumed their present vertical position with a strike parallel to the crest, and that they should have been profoundly modified by chemical action except under conditions of disturbance amply sufficient to have brought about essential modifications of the whole range. That there were at the time, or at least had been previously, mountains in nearly the same position does not impair the claim of this addition to be considered as much a part of the modern Sierra as any older portion. If the conclusions thus far stated are accepted, it follows at once that subsequent to the close of the Knoxville, but long before the beginning of the Chico, both the Sierra and the Coast Ranges experienced an upheaval. This was in all probability not the first in the line of the Sierra and very possibly did not actually originate the Coast Ranges, but for the latter it is the first distinctly traceable movement. It is conceivable that within the limits of time indicated two upheavals should have taken place, one affecting only the Sierra, the other only the Coast Ranges; but the probability of this alternative will scarcely be seriously maintained. The earlier determinable portion of the Coast Ranges must therefore be considered as due to the same disturbance which added the gold belt proper to the Sierra Nevada. There is much probability that a portion at least of the Cascade Range was elevated and metamorphosed at the same time. The relationship thus established is brought out more clearly by a comparison of the history of the ranges so far as it can be traced.

Both the Sierra Nevada and the Coast Ranges were above water and underwent erosion during the interval between the Knoxville and the Chico epochs. Both ranges also sank just before the beginning of the Chico, admitting the ocean over a great part of the Coast Ranges and over considerable areas at the base of the Sierra. Both appear to have risen partially before the Téjon, particularly toward the north; at least, the rocks of this epoch, so far as is known, are confined to the southern extremity of the Sierra and to the Coast Ranges south of Martinez. A subsidence would appear to have taken place before the Miocene; rocks of this age extending along the Sierra far to the north of the Téjon localities, while in the Coast Ranges they lie directly upon the metamorphic at a great number of points, clearly indicating a lower general level than during the preceding epoch. During the Pliocene very little of either range was below water.

Not only was an important uplift of the Sierra Nevada contemporaneous with the first known upheaval of the Coast Range, but, even with the imperfect information at command, it is clear that the successive fluctuations of level of the country since the close of this disturbance have affected these ranges substantially in the same manner, and I cannot but conclude that the new facts brought forward necessitate the reference of the Sierra Nevada and the Coast Ranges to a single mountain system. The Coast Ranges are, and probably always have been, of less altitude than the great Sierra, and they have consequently been more extensively immersed, just as would be the case if both were now to sink any given number of thousand feet. Between the Miocene and Pliocene periods the Coast Ranges also suffered disturbances, in which at least the western base of the Sierra seemed not to have shared. The Sierra, too, has undergone some faulting in which neither the Coast Ranges nor the Basin Ranges have shared; but these differences do not appear to me sufficient to counterbalance the important coincidences in the history of the ranges.

In portions of the Cascades the Miocene rests directly upon the metamorphic as it so often does in the California Coast Ranges, but to the east of the Cascades Chico beds occur, showing that the range was at least broken through at certain points. I greatly incline to the belief, however, that this range is structurally one of the northern continuations of the united Coast Ranges and Sierra Nevada, though but a portion of it may have emerged from the sea at the same time as the more southern ranges. The great valley of California was evidently covered by water in comparatively recent times, as eastern Oregon was in the Chico, and as the Gulf of California is now. Dr. White points out that the occurrence of fossils of the eastern zoölogical province west of the Sierra Madre, shows that the peninsula of California was at one time the line of the barrier between the eastern and western seas. This appears to me conclusive, and yet there is much remaining to be settled as to the relations between the Sierra and the ranges from Arizona southward. They may still turn out to belong to a single system, though at some time the eastern members of the chain may have been broken sufficiently to admit the ocean while the western ranges were intact, just the reverse of the present condition.

The views taken in the foregoing pages have a perhaps not inconsiderable advantage in more closely harmonizing the topography and geology of the west coast. Any good topographical map of the Western United States seems to indicate some such structural relations as those which have been presented here from a geological point of view. Or conversely, if the conclusions reached are accepted, it appears that just as comparatively small fissures, such as are met in mines, are almost never simple, but branch or divide and meet again while following one dominant course, so the great lines of disturbance which have determined the geographical features of a large portion of the country unite, divide, and throw out shoots with an irregularity in detail underlying which a dominant tendency is clearly perceptible. I do not believe that such a system could have come into existence piecemeal, but rather that all its main outlines originated, like the great Wahsatch fault, long before the earliest of our fossiliferous strata.

SAN FRANCISCO, CALIFORNIA, *February*, 1885.

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[Bulletin No. 20.]

The publications of the United States Geological Survey are issued in accordance with the statute, approved March 3, 1879, which declares that—

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Under these general laws it will be seen that none of the Survey publications are furnished to it for gratuitous distribution. The 3,000 copies of the Annual Report are distributed through the document rooms of Congress. The 1,900 copies of each of the publications are distributed to the officers of the legislative and executive departments and to stated depositories throughout the United States.

Except, therefore, in those cases where an extra number of any publication is supplied to this office by special resolution of Congress, as has been done in the case of the Second, Third, Fourth, and Fifth Annual Reports, or where a number has been ordered for its use by the Secretary of the Interior, as in the case of Mineral Resources and Dictionary of Altitudes, the Survey has no copies of any of its publications for gratuitous distribution.

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MONOGRAPHS.

Of the Monographs, Nos. II, III, IV, V, VI, VII, and VIII are now published, viz:

II. Tertiary History of the Grand Cañon District, with atlas, by Clarence E. Dutton, Capt., U. S. A. 1882. 4°. xiv, 264 pp. 42 pl. and atlas of 24 sheets folio. Price $10.12.

III. Geology of the Comstock Lode and the Washoe District, with atlas, by George F. Becker. 1882. 4°. xv, 422 pp. 7 pl. and atlas of 21 sheets folio. Price $11.

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The following are in press, viz:

IX. Brachiopoda and Lamellibranchiata of the Raritan Clays and Greensand Marls of New Jersey, by Robert P. Whitfield. 1885. 4°. ix, 338 pp. 35 pl.

X. Dinocerata. A Monograph of an Extinct Order of Gigantic Mammals, by Othniel Charles Marsh. 1885. 4°. —, — pp. 56 pl.

XI. Geological History of Lake Lahontan, a Quaternary Lake of Northwestern Nevada, by Israel Cook Russell. 1885. 4°. —, — pp. 46 pl.

The following are in preparation, viz:

I. The Precious Metals, by Clarence King.

Geology and Mining Industry of Leadville, with atlas, by S. F. Emmons.

Geology of the Eureka Mining District, Nevada, with atlas, by Arnold Hague.

Lake Bonneville, by G. K. Gilbert.

Sauropoda, by Prof. O. C. Marsh.

Stegosauria, by Prof. O. C. Marsh.

BULLETINS.

The Bulletins of the Survey will contain such papers relating to the general purpose of its work as do not properly come under the heads of ANNUAL REPORTS or MONOGRAPHS.

Each of these Bulletins will contain but one paper and will be complete in itself. They will, however, be numbered in a continuous series, and will in time be united into volumes of convenient size. To facilitate this each Bulletin will have two paginations, one proper to itself and another which belongs to it as part of the volume.

Of this series of Bulletins Nos. 1 to 20 are already published, viz:

1. On Hypersthene-Andesite and on Triclinic Pyroxene in Augitic Rocks, by Whitman Cross, with a Geological Sketch of Buffalo Peaks, Colorado, by S. F. Emmons. 1883. 8°. 42 pp. 2 pl. Price 10 cents.

2. Gold and Silver Conversion Tables, giving the coining value of Troy ounces of fine metal, etc., by Albert Williams, jr. 1883. 8°. ii, 8 pp. Price 5 cents.

3. On the Fossil Faunas of the Upper Devonian, along the meridian of 76° 30′, from Tompkins County, New York, to Bradford County, Pennsylvania, by Henry S. Williams. 1884. 8°. 36 pp. Price 5 cents

4. On Mesozoic Fossils, by Charles A. White. 1884. 8°. 36 pp. 9 pl. Price 5 cents.

5. A Dictionary of Altitudes in the United States, compiled by Henry Gannett. 1884. 8°. 325 pp. Price 20 cents.

6. Elevations in the Dominion of Canada, by J. W. Spencer. 1884. 8°. 43 pp. Price 5 cents.

7. Mapoteca Geologica Americana. A catalogue of geological maps of America (North and South), 1752–1881, by Jules Marcou and John Belknap Marcou. 1884. 8°. 184 pp. Price 10 cents.

8. On Secondary Enlargements of Mineral Fragments in Certain Rocks, by R. D. Irving and C. R. Vanhise. 1884. 8°. 56 pp. 6 pl. Price 10 cents.

9. A Report of work done in the Washington Laboratory during the fiscal year 1883–'84. F. W. Clarke, chief chemist; T. M. Chatard, assistant. 1884. 8°. 40 pp. Price 5 cents.

10. On the Cambrian Faunas of North America. Preliminary studies by Charles Doolittle Walcott. 1884. 8°. 74 pp. 10 pl. Price 5 cents.

11. On the Quaternary and Recent Mollusca of the Great Basin; with Descriptions of New Forms, by R. Ellsworth Call; introduced by a sketch of the Quaternary Lakes of the Great Basin, by G. K. Gilbert. 1884. 8°. 66 pp. 6 pl. Price 5 cents.

12. A Crystallographic Study of the Thinolite of Lake Lahontan, by Edward S. Dana. 1884. 8°, 34 pp. 3 pl. Price 5 cents.

13. Boundaries of the United States and of the several States and Territories, by Henry Gannett. 1885. 8°. 135 pp. Price 10 cents.

14. The Electrical and Magnetic Properties of the Iron-Carburets, by Carl Barus and Vincent Strouhal. 1885. 8°. 238 pp. Price 15 cents.

15. On the Mesozoic and Cenozoic Paleontology of California, by Dr. C. A. White. 1885. 8°. 33 pp. Price 5 cents.

16. On the higher Devonian Faunas of Ontario County, New York, by J. M. Clarke. 1885. 8°. 86 pp. 3 pl. Price 10 cents.

17. On the Development of Crystallization, etc., by Arnold Hague and J. P. Iddings. 1885. 8°. 44 pp. Price 5 cents.

18. On Marine Eocene, Fresh-water Miocene, and other Fossil Mollusca of Western North America, by Dr. C. A. White. 1885. 8°. 26 pp. 3 pl. Price 5 cents.

19. Notes on the Stratigraphy of California, by George F. Becker. 1885. 8°. 28 pp. Price 5 cents.

20. Contributions to the Mineralogy of the Rocky Mountains, by Whitman Cross and W. F. Hillebrand. 1885. 8°. 114 pp. 1 pl. Price 10 cents.

Numbers 1 to 6 of the Bulletins form Volume I, and numbers 7 to 14 Volume II. Volume III is not yet complete.

The following are in press, viz:

21. The Lignites of the Great Sioux Reservation, by Bailey Willis. 1885. 8°. — pp. 5 pl. Price — *cents.*

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22. On New Cretaceous Fossils from California, by Charles A. White, M. D. 1885. 8°. — pp. 5 pl. Price — cents.

STATISTICAL PAPERS.

A fourth series of publications having special reference to the mineral resources of the United States is contemplated.

Of that series the first has been published, viz:

Mineral Resources of the United States, by Albert Williams, jr. 1883. 8°. xvii, 813 pp. Price 50 cents.

The second volume of this series, Mineral Resources 1883 and 1884, is in preparation and will soon be put to press.

Correspondence relating to the publications of the Survey, and all remittances, which must be by POSTAL NOTE OF MONEY ORDER, should be addressed

To THE DIRECTOR OF THE
UNITED STATES GEOLOGICAL SURVEY,
Washington, D. C.

WASHINGTON, D. C., *May* 25, 1885.

DEPARTMENT OF THE INTERIOR

BULLETIN

OF THE

UNITED STATES GEOLOGICAL SURVEY

No. 20

WASHINGTON
GOVERNMENT PRINTING OFFICE
1885

UNITED STATES GEOLOGICAL SURVEY
J. W. POWELL DIRECTOR

CONTRIBUTIONS
TO THE
MINERALOGY OF THE ROCKY MOUNTAINS

BY

WHITMAN CROSS and W. F. HILLEBRAND

WASHINGTON
GOVERNMENT PRINTING OFFICE
1885

LETTER OF TRANSMITTAL.

UNITED STATES GEOLOGICAL SURVEY,
DIVISION OF THE ROCKY MOUNTAINS,
Denver, Colo., March 1, 1885.

SIR: I have the honor to transmit herewith a paper by Messrs. W. Cross, assistant geologist, and W. F. Hillebrand, chemist, representing work that has been done by them in the office and laboratory of this division, at intervals of leisure from their regular duties, during the past three years. Believing that the results of their investigations form a valuable contribution to the mineralogy of the Rocky Mountains, I would respectfully suggest that they be published in the form of a bulletin, so that they may be made immediately available to those interested in this science.

Very respectfully, your obedient servant,

S. F. EMMONS,
Geologist in Charge.

Hon. J. W. POWELL,
Director United States Geological Survey.

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CONTRIBUTIONS TO THE MINERALOGY OF THE ROCKY MOUNTAINS.

By Whitman Cross and W. F. Hillebrand.

INTRODUCTORY REMARKS.

A large part of the subject-matter contained in the following pages has already appeared in print, at various times during the past four years, in the American Journal of Science or the Proceedings of the Colorado Scientific Society. As opportunity has offered, the studies have been extended upon the old or upon new and better material, so that much of that which has been previously published is here presented in a revised or enlarged form. The desirability of collecting in one place the notices of minerals from the same general region has led to the reproduction of some descriptions unaltered.

The more purely mineralogical parts of Sections I and II, for which the first-named author is chiefly responsible, does not claim to be so thorough and exact in many cases as the nature of the material may render desirable. This is partially explained by a want of the proper instruments for use in determining certain optical and physical properties of the minerals, but still more fully by the fact that the geological investigations in progress have left but little time for pure mineralogy.

In regard to the chemical part of the work a few remarks are necessary. From the first establishment of a laboratory in Denver a special aim has been to make the analytical work as thoroughly accurate as possible even though the amount accomplished should in consequence be lessened. As the main part of the laboratory work consists in investigations upon eruptive rocks, an exact knowledge of whose composition is at present deemed of great importance, it was sought to reduce the errors ordinarily incident to analyses of such rocks to the smallest possible limits. To this end none of the ordinary reagents employed in any quantity are used without being first subjected to careful analysis. If they are found to contain sufficient impurity to influence even to a slight extent the result of an analysis, they are either rejected altogether or purified, or the percentages of impurities present are estimated and deducted from each analysis, for which weighed or measured quantities of these reagents are employed. Thus the very small quantities of silica, ferric oxide, alumina, and lime, almost invariably to be found in the purest of sodium carbonate, in a measure due to dust that has collected in the process of manufacture and packing, and which will generally influence the result of an analysis from 0.1 to 0.2 per cent., are allowed for. Ammonia, which, after being kept in carboy for some length of time, often contains large amounts of silica and other foreign matter, is redistilled and collected in pure water every few weeks.

By taking such precautions and using wherever possible platinum vessels, with proper care a high degree of accuracy is attainable. Especially is this so when no solid reagents enter into an analysis, as in the case of zeolites, of which a large number of analyses appear on subsequent pages and in few of which the sum total of percentages exceeds 100.1. A long series of analyses of eruptive rocks has been made in which, during the past two years, it has been the rare exception for an analysis to foot up over 100.2.

Without these explanatory remarks the close approximation to 100 per cent. shown by so many analyses might rather inspire distrust than confidence.

I.—MINERALS FROM THE BASALT OF TABLE MOUNTAIN, GOLDEN, COLORADO.

By Whitman Cross and W. F. Hillebrand.

DESCRIPTION OF TABLE MOUNTAIN.

Table Mountain is a plateau or *mesa* with an area of from 4 to 5 square miles, situated upon the border of the great plains, 12 miles west of Denver, approaching so closely to the abruptly rising foot-hills, composed of Archæan rocks, that the intervening space is not more than 1 mile in width. Within this space, however, are exposed the upturned edges of strata of the Triassic, Jurassic, and Cretaceous ages, including in the latter the coal-bearing Laramie formation, all dipping steeply eastward. The mountain owes its existence to a sheet, or rather, in most places, to two sheets of basalt, which have in a measure protected the underlying soft Tertiary beds from erosion, which has removed the upturned Mesozoic strata to the west, until a valley several hundred feet deep has resulted, separating Table Mountain from the foot-hills. The Tertiary strata below the basalt are horizontal, and seem at first glance unconformable with the Mesozoic, but this is largely due to the location of the valley of erosion in a sharp fold; in other places apparent conformability is shown.

Clear Creek issues from the foot-hills opposite the mountain, and has cut a gorge directly through it, dividing it into what are known as North and South Table Mountains, which have an average elevation above the creek bed of about 700 feet. On the banks of the creek behind the mountain is situated the town of Golden.

The source of the basalt is in certain dikes situated to the north and northwest, whence the lava spread out in sheets and flowed to the south-southeast. The lower sheet averages 100 to 115 feet in thickness and possesses the structure of a stream which has flowed upon the surface. Adjacent to the underlying strata is a layer of a very porous structure about 1 foot in thickness, then follows massive compact rock for 70 feet, while the upper 40 to 50 feet show many cavities, large and small, more or less flattened and drawn out, and the surface is rough and jagged. The first sheet was covered by a second, of identical composition, before erosion or decomposition had produced noticeable effects.

Of the second sheet only the massive lower part remains, and its thickness, as well as the lateral extension of both sheets, can only be a matter of conjecture. The rock is a feldspar basalt of very simple composition, rather coarsely crystalline in its massive parts, and in the porous part with a groundmass which becomes finer grained as it approaches the contact or the surface. A glassy base, now much devitrified, was formerly present in the porous parts.

In the cavities of the upper portion of the lower sheet are many beautifully crystallized zeolites, associated with calcite and aragonite. The mode of occurrence varies somewhat in different parts of the mountain, and a few species seem to be locally restricted, but most of those to be described can be found in abundance and well developed.

At a point on the southern face of North Table Mountain, where the greatest number of species occur together, the students in the School of Mines at Golden began blasting for specimens several years ago. During the present investigations the locality was still further opened and absolutely fresh and clear material was obtained.

The only previous notice of this mountain is embodied in the report of Arch. R. Marvine, in the Annual Report of the United States Geological and Geographical Survey of the Territories for the year 1873, pp. 129–131, but the information given is exceedingly meager and in part incorrect.

The Survey is indebted to Prof. A. Lakes, of the School of Mines, for calling special attention to Table Mountain.

MANNER OF OCCURRENCE OF THE MINERALS.—The following mineral species have been identified in the cavities of the basaltic sheet, viz.: analcite, apophyllite, chabazite, levynite, thomsonite, mesolite, natrolite, scolecite, stilbite, laumontite, calcite, and bole. Of the occurrence of these species a few remarks will be in place before proceeding to detailed descriptions.

Primarily one can distinguish between the minerals occurring in fissures and those in the roundish cavities of the amygdaloidal zone. On both mountains are many fissures and irregular cavities having outward communication, in which calcite, bole, and reddish zeolites are almost always deposited. Occasionally colorless zeolites (analcite or natrolite) appear in fissures, but it is much more characteristic to find them in the closed cavities. On the other hand a reddish, horizontally stratified zeolitic deposit is found in many amygdaloidal cavities, filling the smaller ones completely or forming a floor in the larger ones. As the minerals developed here are in part the same as those found in adjacent fissures, and as these reddish deposits always precede in time the formation of the colorless zeolites, it seems probable that all the cavities containing the minerals in question were formerly penetrated by fissures. Some such explanation is necessary, for cavities containing the reddish zeolites occur side by side with those in which only members of the other group are present. In some few cases, small fissures, now filled, were found leading into cavities containing the stratified deposits.

The zeolites are then naturally divisible into two groups, according to mode and time of formation, the first containing laumontite, stilbite, and thomsonite; the second, stilbite and thomsonite, with all the other species of the above list. They will be thus considered in the following description.

ORDER OF DEPOSITION.—Considering all the species which occur in associations allowing inferences as to relative age, the following may be given as the order observed, beginning with the oldest:

1. Laumontite.
2. Stilbite. } Red or yellowish.
3. Thomsonite.
4. Calcite (yellow).
5. Stilbite.
6. Chabazite.
7. Thomsonite.
8. Analcite.
9. Apophyllite.
10. Calcite (colorless).
11. Mesolite.

Chabazite and thomsonite were also formed again in very small quantity, probably between 9 and 10. Natrolite, scolecite, and levynite do not occur in direct association with most of the above, so that their places in the series are unknown.

ZEOLITES. FIRST GROUP.

GENERAL.—The minerals of this group are best developed in the stratified deposits of the amygdaloidal cavities, where also the order and manner of deposition can most clearly be seen.

In a large cavity containing a floor of the reddish-yellow mixture of the minerals of this group, it is at once noticed that the roof and sides above the level of the stratified mass show no trace of any one of these species. From this fact and from the structure of the mass the inference is warranted that the formation began at the bottom and proceeded very rapidly to its close. Usually the lower portion of such masses is composed of a reddish-yellow mineral in irregular grains, forming a compact aggregate in which lie isolated spherules of a similarly colored radiate mineral. These spherules are seldom more than 2^{mm} in diameter and are very perfect spheres. They increase in number upward and finally compose the greater part of the deposit.

In one cavity, 6 to 8 feet in horizontal diameter and about 2 feet in height, the deposit is quite different. Here the main mass is loosely granular, and is formed chiefly by a bright greenish-yellow mineral, while a stratified appearance is produced by layers of a white or colorless substance.

Some of the light layers are chiefly made up of easily recognizable stilbite, and the same mineral in distinct tablets forms the upper layer of the whole deposit. There are also irregular seams of white running through the yellow material.

LAUMONTITE.

DESCRIPTION.—If the loose sand from the above-mentioned cavity be placed under the microscope with a power of about 15 diameters, it is seen to consist of prismatic grains, mostly with broken terminations. Many of the grains are clear and transparent, with the greenish-yellow color mentioned, while others are dull. The clear prisms polarize strongly, and extinction upon a prismatic plane takes place at an angle of 35° to 40° with the vertical axis.

On splitting open some of the white layers, surfaces are obtained showing minute stout prismatic crystals, which seen under the microscope present the same habit as the yellow grains. The prism angles are nearly 86° and 94°, and the termination is usually formed by an oblique plane, like a hemidome of the monoclinic system. The optical orientation is the same as in the yellow crystals and corresponds also to the requirements of the monoclinic system so far as can be determined. The properties given agree with those of laumontite, and in the light of the chemical analyses the identification of both yellow and white crystals with that mineral seems entirely justifiable.

CHEMICAL COMPOSITION.—The analysis gives the following results:

	I.—Yellow grains.	II—White crystals.
SiO_2	51.43	52.07
Al_2O_3	21.52	21.30
Fe_2O_3	0.94	....
CaO	11.88	11.24
K_2O	0.35	0.42
Na_2O	0.19	0.48
H_2O	13.81	14.58
(W. F. Hillebrand.)	100.12	100.09

Oxygen ratios:

$$RO : R_2O_3 : SiO_2 : H_2O$$

I. 1 : 2.97 : 7.83 : 3.50

II. 1 : 2.94 : 8.15 : 3.81

(In all calculations of ratios 27 is taken as atomic weight of Al.)

These analyses represent the composition of air-dried material, and the percentages were calculated from the analyses published in the

American Journal of Science.[1] The latter were made after drying over sulphuric acid, it having been observed that at 100° C. an unexpectedly large loss took place, steadily increasing as the temperature rose above 100°. Even when simply dried over sulphuric acid the loss in the case of I was 0.60 per cent., and in the case of II was 1.45 per cent. These abnormally large losses, coupled with still larger ones observed subsequently in analyzing other zeolites, seemed to indicate that all, or at any rate nearly all, the water removed by sulphuric acid should be counted with the water of crystallization, especially as when this was done the oxygen ratios generally more nearly approached that required by theory; for example, in II the ratio for material dried over sulphuric acid is only 1 : 2.94 : 8.15 : 3.42, instead of 1 : 2.94 : 8.15 : 3.81 as above given. Recent investigations by Jannasch[2] on heulandite and epistilbite tend to confirm us in this opinion.

The ratio of II agrees fairly well with the theoretical requirements of laumontite, 1 : 3 : 8 : 4, especially as it can hardly be supposed that the material was absolutely pure. It is quite probable that a small amount of stilbite was included with the material analyzed, which would explain the rather high value for SiO_2.

In regard to the amount of water found it is only necessary to suppose that the dull particles have lost a part of their water while the transparent grains are entirely fresh in order to explain the relation of water to the other constituents as shown in the above ratios, a supposition in full accord with the characteristic tendency of laumontite to lose its water on exposure.

The mineral is not quite so easily fusible before the blow-pipe as typical laumontite should be according to the text-books, but the difference is not sufficiently pronounced to be considered abnormal.

MIXED ZEOLITES.

GENERAL DESCRIPTION.—Turning now to the more compact reddish-yellow deposits, which correspond so closely to the one described above, the same constituent minerals were sought for. Some small cracks or fissures were noticed, usually ending blindly in the yellow mass, some of which were only partially filled with minute white crystals. On splitting the mass open along such a half-filled crack two surfaces were obtained, coated with minute but exceedingly perfect clear crystals, easily recognizable under the microscope as laumontite and stilbite. The little crystals of the former show occasionally the clinopinacoid and a steep positive orthodome in addition to the prism and base.

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[1] III, Vol. XXIII, p. 135.

[2] Neues Jahrbuch für Mineralogie, etc., 1884, II, 206.

The sand obtained by simple fracture of the yellow massive portion on being placed under the microscope is seen to consist largely of fragments of tabular crystals, the angles of which, so far as they are determinable, correspond to stilbite. The grains which are not evident fragments of tablets are in part roughly prismatic, though seldom showing definite faces; neither could the optical action be satisfactorily determined.

CHEMICAL COMPOSITION.—Chemical analyses were made from two different specimens of the yellow granular mass, care being taken to exclude all reddish spherules. The results are given under III and IV below.

	III.	IV.
SiO_2	54.20	53.87
Al_2O_3	17.26	17.26
Fe_2O_3	0.77	0.74
CaO	8.35	8.27
K_2O	0.17	0.07
Na_2O	1.38	1.48
H_2O	18.09	18.44
(W. F. Hillebrand.)	100.22	100.13

Oxygen ratios:

	RO	R_2O_3	SiO_2	H_2O
III.	1	3.01	10.43	5.80
IV.	1	3.03	10.42	5.95

Analyses III and IV were published in the American Journal of Science, with this difference, that they represented the composition of dried material. Inasmuch as III lost 2.14 per cent. of moisture in two days over sulphuric acid (no further loss in three days) and IV 1.69 per cent. under similar conditions, the whole is counted as water of crystallization for the reasons given in discussing the analyses of laumontite.

As will be seen later, pure crystals of colorless stilbite from Table Mountain do not possess, as regards SiO_2 and H_2O, quite the theoretical composition of that mineral (see analysis VI, p. —). If, however, that analysis represents the composition of all stilbite from this locality, these analyses III and IV correspond remarkably well to mixtures of much stilbite with a little laumontite, as was surmised from microscopical examination of the material.

It seems remarkable that the material from two different cavities should contain the two minerals in so nearly the same proportions as is indicated by the analyses.

THOMSONITE SPHERULES.

CHEMICAL IDENTIFICATION.—Concerning the reddish spherules no data of importance could be obtained except by chemical analysis, Under V is given the composition found for this substance in material which was apparently very pure.

	V.
SiO_2	40.52
Al_2O_3	29.22
Fe_2O_3	0.79
CaO	12.43
Na_2O	4.31
H_2O	12.79
(W. F. Hillebrand.)	100.06

The oxygen ratio for this is:

$$RO : R_2O_3 : SiO_2 : H_2O$$
$$1 : 3.00 : 4.63 : 2.44$$

These figures agree so well with those obtained for the colorless thomsonite (see page 25) that in the absence of anything to the contrary the identity of the two substances can scarcely be doubted. It was noticed here, as in the other thomsonite, that about 2 per cent. of the water could be expelled only at a very high temperature. The ferric oxide in all these minerals seems to replace a portion of the alumina.

Thomsonite in the form of these reddish spherules has been deposited locally in great abundance in irregular cavities on the upper surface of the lower sheet of basalt and also in the angular spaces formed where the scoriaceous crust of the flow has been broken or crumpled. It is here deposited alone, free from stilbite and laumontite, but the spherules are exactly similar in size and appearance to those formed in the cavities below.

ZEOLITES. SECOND GROUP.

STILBITE ("DESMIN" GERMAN).

GENERAL.—As has been already mentioned, stilbite occurs occasionally in clear, colorless crystals, as well as in the manner characteristic of the first series. It is noteworthy that in all such cases as yet observed the clear stilbite is either deposited upon the colored zeolites of the group described, or in close proximity to them, although it may be associated with chabazite or clear thomsonite, species having no such limitation. When these three minerals are associated it is sometimes difficult to assign an order of deposition, as they seem to have been nearly contemporaneous. The tablets of stilbite are usually attached by an edge, projecting at various angles from the underlying surface, and rarely appear so abundantly as to form a crust.

CRYSTAL FORM AND OPTICAL PROPERTIES.—The largest crystals seen measure about 1.5^{cm} in longest diameter and 2.3^{mm} in thickness, These crystals, however, are made up of several plates, which are not in exactly coincident orientation, and their surfaces are not very smooth or glistening, from which causes they are not available for either crystallographical or optical studies. For these purposes only the minute transparent tablets which are occasionally found intermingled with the others could be used.

These tablets have the usual rhombic symmetry which has been explained by von Lasaulx as the result of a double twinning of a monoclinic groundform isomorphous with those of harmotome and phillipsite, and according to the laws observed in those species. The isomorphism thus pointed out has been advocated from the chemical side by Fresenius.[3] The Table Mountain stilbite presents some structural and optical properties not fully in accord with the statements of von Lasaulx, and yet the material is not perfect enough to show the full significance of the disagreement. A description of the observed variation may lead to an explanation based upon the study of other and better material.

Assuming the isomorphism stated, the predominant face is $\infty P \breve{\infty}$, while ∞P and $0 P$ are always present, and $+ P \bar{\infty}$ occasionally. The front prism angle was measured at 118° 22′, by attaching small flakes of mica to the dull surfaces of a large crystal, while approximate measurements in the othodiagonal zone could be made under the microscope.

For optical examination a number of small tablets were mounted in balsam, lying upon the predominant pinacoidal face; others were mounted in the same position after a little grinding, which was intended simply to remove impurities from the surface. All exhibit the same optical action. The larger crystals could not be used for the reasons stated above.

Fig. 1 of the plate represents the structure described by von Lasaulx[4] in crystals examined by him, the figure being copied from his article, with a simple inversion to correspond with Figs. 2 and 3. On examining a crystal of tabular form, mounted as above described, between crossed nicols, there appears a division into four quadrants, *a a* and *b b*, by lines passing through the centre parallel and normal to the clino-axis. By parallel position of these lines with the principal sections of the nicols all four portions appear equally dark, but the maximum of extinction is only obtained by a revolution of about 5° from this position, for two diagonally opposite quadrants when the revolution is to the right, for the other two when to the left. There is therefore a difference of about 10° in extinction of adjoining quadrants. According to von Lasaulx the bisectrix is inclined 5° to the clino axis, while the optical normal makes an angle of 34° with the vertical axis. Reference will be made to this point later. A distinct zonal structure parallel to the outlines of $0 P$, and ∞P is described, and a very faint subdivision of each quadrant by this zonal structure is mentioned, but it is distinctly stated that no corresponding optical division exists. It is noted, however, that in a given quadrant the extinction adjoining *d* may be slightly less than that near *c*. Aside from this division into quadrants, which is in agreement with the supposed symmetry and twinning of the mineral as isomorphous with harmotome and phillipsite, there are often four other fields, *c c* and *d d*. The portions *c c* are diverging bundles of a somewhat fibrous, colorless mass, producing in all positions brilliant aggregate polarization. The parts *d d* are made up of bars placed perpendicularly to the line of $0P$, the area thinning out wedge-like toward the centre. Sections situated in the orthozone show coincident extinction throughout, so that these irregular aggregates (*c* and *d*) seem to consist of stilbite substance having at least the orthoaxis in common with the rest. In all the many occurrences examined by von Lasaulx this division is more or less distinct. The portions *c* and *d*, termed by him "inverse substance," in contrast to the normal quadrants *a* and *b*, sometimes predominate largely, while *d* at least is occasionally very subordinate. With this action as given by von Lasaulx will now be compared that exhibited by the Table Mountain stilbite.

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[3] Zeitschrift für Krystallographie, III, 42, 1878.

[4] "Ueber den Desmin." Zeitschrift für Krystallographie, II, 576, 1878.

Fig. 2 represents the optical behavior of a crystal from Table Mountain, and is typical of that in all examined. It is in parallel position with Fig. 1, the dome $+P\bar{\infty}$ being added while at one end is a repetition of ∞P and $P\bar{\infty}$. The same primary divisions are here seen as in Fig. 1, but each quadrant, *a*, is clearly subdivided when seen in polarized light by the zonal structure, which in the octants *a* and *b* runs parallel to the outline of ∞P, in *a′* and *b′* parallel to $0P$. The two systems meet in an irregular line which usually runs from the angle between $0P$ and ∞P to the centre of the crystal. The bands of the two systems do not cross each other, as represented in Fig. 1, and a very small but appreciable variation in optical orientation may be seen. The direction of extinction in *a′* and *b′* measures about 4° 15′ from the edge of $0P$, while in *a* and *b* it is 5°–5° 30′ from the same direction. This corresponds to the statement of von Lasaulx that there seemed to be in some cases a difference between the extinction of *a* near the space *d* and that near *c*, the latter being greater. So far the action might be considered as slightly more intense than usual, whereby the subdivision of the quadrants is plainer. However, the position of the optical normal as given by von Lasaulx demands that the bisectrix should cut the clino axis, *i. e.*, the line of $0P$ in the figure, at an angle of about 5° and the vertical axis at about 56°, while the bisectrix in the present case is inclined 5° to the clino axis and about 46° to the vertical axis, the normal consequently intersecting the latter at about 44°. In all crystals and in each quadrant the bisectrix lies in a dome which is steeper than the basal plane by about 5°, and hence truncates the angle between $0P$ and ∞P, bringing the optical normal to an inclination of about 44° with the vertical axis. The close agreement in other respects suggests the possibility that the position of the bisectrix relative to the clino axis may have been transposed by von Lasaulx.

The portions lettered *c* in Fig. 2 correspond in position and character to those of Fig. 1. An attempt has been made to indicate their irregular form and their relation to other parts. Usually based upon the outline of $P\overline{\infty}$, they may spring from any part of the line of ∞P, and universally run toward the centre, often wedging out before reaching it and never penetrating segments *a′* or *b′*. Parts corresponding to *d d* in the Fig. 1 are here represented by a few bars at right angles to $0P$, but, although most numerous near the sharp line between *a′* and *b′*, they do not appear in sufficient quantity to form a distinct field, as *d* in Fig. 1. These interpositions seem most probably to be portions of *a′* included in *b′* and *vice versa*. The lower part of Fig. 2 shows the irregular relation of *b′* to *a′* in some cases, the dividing line being sharp while very much broken. In *b′*, which is thus enlarged, are numerous interpositions which are most sharply defined and apparently thickest on the side opposite *a′*, while thinning out toward that area. Some bars in *b′* seem to have a thin wing-like appendage on the side next *a′*. The orientation of these interposed bodies cannot be definitely ascertained, but they seem to correspond closely to the adjacent division of the next quadrant.

The areas *c c* often contain stripes corresponding to *a* and *b* and also more rarely of *b′* or *a′*. Fig. 2 shows how each repetition of ∞P is accompanied by portions which are banded parallel to its outline and correspond optically to all other parts of the same position. In some crystals a close examination shows a delicate zonal structure, parallel to that of *a* or *b*, in small irregularly shaped parts of *c*, and as these are almost always thin and underlaid by substance of other orientation, so that a uniform extinction does not take place, it seems quite probable that these portions showing aggregate polarization are made up of an intergrowth of thin flakes of *a* and *b* with the ortho axis in common, but not in fully coincident position otherwise; corresponding thus to the known tendency of the mineral in larger crystals and which is characteristic of those from this locality. Von Lasaulx also suggests this explanation, but thinks the brilliant and strongly contrasted polarization of parts whose extinction angles should so nearly coincide is antagonistic. The interference of light in passing numerous laminæ and possible tension arising from the manner of intergrowth assumed seem, however, sufficient to account for this strong action.

During the study of the twin structure in phillipsite, Trippke[5] made a section through the centre of a double twin crystal, parallel to the clinopinacoid of one of the simple twins and obtained thus a form cor-

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[5] P. Trippke. "Beiträge zur Kenntniss der schlesischen Basalte und ihrer Mineralien." Breslau, 1878. (Dissertation.)

responding to the crystals of stilbite. Fig. 3 is a reproduction from his work showing the optical division of the section. Its formal correspondence with that described for stilbite is noteworthy. The segments *a* and *b* correspond to *a′* and *b′* of Fig. 2, even to the interposed bars at right angles to 0 P, which are interpreted by Trippke as inclusions of *a* substance in *b*, and the reverse (loc. cit., p. 39). The areas *c*, *d′*, *f*, *e′* represent, however, four distinct individuals which do not correspond to *a* and *b* of Fig. 2, except in form. Likewise the wedge-shaped portions *a′* and *b′* do not correspond to *c* of the stilbite, for they represent substance whose basal plane falls parallel to $\infty P \bar{\infty}$ of *a* and *b*. If the various parts of the stilbite crystals do possess the ortho axis in common, as indicated by the observations of von Lasaulx and by a single section secured parallel to 0 P in a Table Mountain crystal, then the structural correspondence between Figs. 2 and 3 is meaningless except for the segments based upon 0 P. These are actual equivalents.

The material thus far obtained from Table Mountain does not permit of crystallographic measurements of sufficient accuracy to determine definitely whether the division into octants, indicated by the optical behavior, can be traced in the outer form or not. The incomplete results obtained have been given in detail because it seems probable that the material examined by von Lasaulx does exhibit in less distinct form the same action. It is hoped that an attempt to secure better specimens from Golden may be successful, so that further examination may be made.

ANALYSIS.—Pure crystals gave on analysis the following:

	VI.
SiO_2	54.67
Al_2O_3	16.78
CaO	7.98
Na_2O	1.47
H_2O	19.16
(W. F. Hillebrand.)	100.06

Oxygen ratio:

$RO : R_2O_3 : SiO_2 : H_2O$

1 : 2.97 : 10.97 : 6.41, instead of

1 : 3.00 : 12.00 : 6.00, as required by the ordinarily accepted formula.

CHABAZITE.

GENERAL.—With the exception of stilbite this is the oldest of the colorless zeolites. In most cases where several zeolites occur together chabazite forms the lining of the cavity and the others are deposited upon it. It is often found alone, however, and excellent specimens are abundant.

The glassy white, or rarely pinkish, crystals have the usual rhombohedral form and the faces are occasionally as much as 1^{cm} in diameter.

The crystals are usually twins of interpenetration. In some of the smaller cavities are subdividing walls of chabazite or miniature columns composed of many small crystals. A second generation of chabazite came after thomsonite and analcite, but the crystals are few and very minute.

CHEMICAL COMPOSITION.—Chemical analysis of clear crystals gave as follows:

	VII.	VIII.
SiO_2	47.86	47.18
Al_2O_3	19.30	19.67
Fe_2O_3	*0.12	......
CaO	9.94	9.74
SrO		0.43
K_2O	0.35	0.37
Na_2O	0.52	0.51
H_2O	22.07	22.15
(W. F. Hillebrand.)	100.16	100.05

* From attached limonite.

	Per cent.
Loss on drying over sulphuric acid	2.66
Total loss at 100° C	4.76
Total loss at about 300° C	18.45
Loss above 300° C	3.70

From the above analyses it is impossible to deduce a formula strictly in accordance with that of Rammelsberg[6] or that of Streng.[7] Assuming part of the alkaline earths to be replaced by alkalies, the following oxygen ratios are obtained:

$$\begin{array}{lccccccc} & RO & : & Al_2O_3 & : & SiO_2 & : & H_2O \\ VII. & 1 & : & 3.05 & : & 8.57 & : & 6.59 \\ VIII. & 1 & : & 3.04 & : & 8.27 & : & 6.47 \end{array}$$

It is highly probable that a part of the water is basic. The presence of strontia in such quantity is noteworthy.

The material was not examined microscopically.

THOMSONITE.

OCCURRENCE AND GENERAL DESCRIPTION.—This zeolite followed closely upon the chabazite; indeed its earliest aggregates are so intimately associated with that mineral as to make it evident that the deposition of the one had begun before that of the other had ended. The mineral occurs in very minute rectangular blades, which are placed upon each other like the leaves of a closed fan, and the very compact combinations of such aggregates are usually arranged in a more or less distinct radiate manner. Sometimes spherical forms result, in other cases columns, by radiation from an axis, or, less frequently, walls, the blades standing at right angles to the central plane. Where crystals of yellow calcite were not covered by chabazite the thomsonite has never failed to coat them, the blades being approximately perpendicular to the crystal faces. When a large surface of chabazite has been completely coated by the more or less radiate aggregates of thomsonite, forming an undulating surface, the whole has a most delicate silken lustre, while that on a fractured surface of a spherical mass is more satin-like. The aggregates are white when pure and single blades are transparent.

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[6] Zeitschrift d. D. geol. Ges., XXXVI, 220, 1884.

[7] Berichte d. oberhess. Ges., etc., XVI, 74, 1877.

It is difficult to obtain isolated leaves, and they are then so thin as to affect polarized light but slightly, still it was definitely determined that the direction of total extinction between crossed nicols is parallel to the longitudinal axis. By examination of the ends of the blades under the microscope with a power of 90 diameters, it could be seen that the vertical edges were formed in many cases by a plane at right angles to the dominant surface. Occasionally a prism was found with angle very near 90°, and in a few cases both forms together were seen. These planes correspond to the macropinacoid (dominant) prism and brachypinacoid of thomsonite, as given by all authorities. The termination seems to be the basal plane. The average thickness of these blades is about 0 01^{mm}. Toward the close of the zeolitic formation a second generation of thomsonite was deposited. The blades are in this case longer than in those of the first while the other dimensions remain about the same. In combination with the base upon the crystals of this latter growth are apparent brachydomes, whose angles with the base were most frequently measured at about 145° or 135°.

The blades of the second generation, when deposited upon those of the first, have the same crystallographic orientation and serve simply as prolongations of the latter. Through the usual slight yellow tinge of the recent growth, the line between the two is clear. The long blades of the second growth of thomsonite often form bundles resembling rough prismatic crystals, and these bundles arranged in a loosely and irregularly radiate manner form bunches an inch or more in diameter upon which the delicate needles of mesolite have a special tendency to deposit themselves.

The thomsonite of Table Mountain was first identified through a quantitative analysis by Carlton H. Hand, at the time a student in the School of Mines at Golden. The analysis was not published and has been lost.

CHEMICAL COMPOSITION.—The following results were obtained by the analysis of different specimens of thomsonite from Table Mountain:

	IX.	X.		XI.		XII.		XIII.
		a	b	a	b	a	b	
SiO_2	40.88	40.68	40.70	41.21	41.17	42.66	....	41.63
Al_2O_3	29.68	30.12	29.75	29.71	....	29.25	29.29	....
CaO	11.88	11.92	11.89	11.34	11.38	10.90	10.90	....
Na_2O	4.72	4.44	....	5.62	....	4.92	....	....
H_2O	12.91	12.86	....	12.20	....	12.28	12.34	....
(W. F. Hillebrand.)	100.07	100.02	....	100.08	....	100.01	....	....

Oxygen ratios:

	RO	R_2O_3	SiO_2	H_2O
IX	1	3.03	4.73	2.49
X, mean of *a* and *b*	1	3.09	4.77	2.51
XI, mean of *a* and *b*	1	2.98	4.68	2.31
XII, mean of *a* and *b*	1	3.14	5.19	2.50

DISCUSSION OF ANALYSES.—In all of these analyses the figures under *b* denote repeated determinations. Analysis IX was made upon material taken from the purest and finest specimen of thomsonite as yet obtained. Separation from the underlying thin layer of chabazite was complete. The material for X was also selected with the greatest care from a very pure specimen. Imperfectly spherical aggregates were broken up quite finely, and each particle appropriated for analysis was first closely examined with a strong lens in order to detect any trace of chabazite. Thinking it possible that a small amount of chabazite might have escaped notice, a second portion of thomsonite from the same specimen was procured by breaking off the ends of the blades, and this was found to contain 41.63 per cent. of SiO_2 (XIII). A microscopical examination of this material showed that these blades of thomsonite contained very small, irregularly rounded particles imbedded in the outer surfaces. These particles, which are clear or slightly yellowish, do not affect polarized light perceptibly and are not crystalline in form. They are present in varying quantity toward the termination of nearly all blades, but are usually entirely wanting in the lower portions of all aggregates. In the material yielding IX they were present in less quantity than usual, and even if they consisted of pure silica could have affected the result but slightly.

Analyses XI and XII were made upon substance known to be slightly contaminated by delicate hairs of mesolite which could not be fully removed. Both represent thomsonite from bunches of the kind mentioned above.

RELATION TO "MESOLE."—In the hope of throwing some light upon the cause of the difference between the composition of normal thomsonite (oxygen ratio 1 : 3 : 4 : 2½) and the variety sometimes called "mesole" (oxygen ratio well represented by those of the foregoing analyses), the ratios for all the analyses of mesole given in Dana's System of Mineralogy, and of such others as could be obtained, were calculated and the results examined.

Intermixture of free silica or of mesolite has been generally considered the cause of the excess of silica in mesole. While the presence of either or both of these substances may be a sufficient explanation in some instances, and in two of the above analyses (IX and X) undoubtedly is, to some extent at least, a true one, it will not answer for a majority of the published analyses examined. Only one of these, on

Nova Scotia material, by How, affords a ratio very near that furnished by IX and X above.

While positive proof is wanting of the total absence of free silica in the purest of the Golden thomsonite analyzed, the most thorough microscopical examination failed to reveal its presence or that of any other foreign matter.

Mesolite cannot be the disturbing element here, because in order to raise the silica 3 per cent. above that of normal thomsonite there would be required an admixture of not far from 50 per cent. of mesolite, which amount would also have raised the oxygen value for water. It seems indispensable to a solution of this question that numerous and accurate analyses should be made of this variety of thomsonite from as many localities as possible, and that careful microscopical examination should in every case furnish as far as possible a guarantee of the purity of all material taken for analysis.

ANALCITE.

General Description.—Analcite follows thomsonite in time of deposition. At the locality mentioned on North Table Mountain its crystals are pure white or transparent and vary in size from very small ones to those nearly an inch in diameter. The predominating form is the common trapezohedron 202 having its octahedral edges evenly truncated by $\frac{3}{2}$0. The appearance of $\frac{3}{2}$0 is very characteristic of the Table Mountain analcite, though the form is never prominent and is usually represented by an exceedingly narrow line. According to Zirkel[8] the form $\frac{3}{2}$0 has been observed but once on analcite, viz., by Laspeyres on that from the Kerguelen Islands. A second generation of analcite was observed, analogous to that of chabazite, the crystals being very small and clear. They were deposited upon apophyllite.

On the eastern side of North Table Mountain analcite is often present alone, filling small cavities completely and developed in immense crystals in the larger ones, some being nearly 2 inches in diameter. The faces of such large crystals are often uneven through depressions or other irregularities bounded by faces of 202.

On South Table Mountain analcite is more abundant than any other zeolite. Large cavities have a floor of analcite but always in quite small crystals. Natrolite is almost invariably deposited upon it and frequently small cracks are filled with the same mineral associated with calcite or natrolite. Analcite was also found in spaces between the pebbles of a conglomerate bed, not far below the basalt, the pebbles being of basic eruptive rocks.

Optical Behavior.—The anomalous optical properties of much analcite have been the subject of careful investigation by numerous able mineralogists, some of whom have sought the explanation in a complicated twin structure by which a substance of lower degree of symmetry may imitate a higher, while others have referred the phenomenon to double refraction arising from inner tension. Since the exhaustive researches of Ben-Saude[9] few have opposed the latter view, according to which all optical action in analcite, which is abnormal for a mineral crystallizing in the regular system, is regarded as secondary and produced by molecular disturbances due to changes of temperature. The mode of formation of the mineral and the crystal forms developed determine the character of the anomalous action.

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[8] Naumann-Zirkel, "Elemente der Mineralogie." Leipzig, 1881.

In the preliminary description of the Golden zeolites[10] it was stated that the analcite of Table Mountain "is doubly refractive, but so irregularly that it cannot be well used in confirmation of the interesting observations of Ben-Saude." At about the time of this publication a suite of the Golden zeolites was sent to Professor Carl Klein, of Göttingen, the foremost in the group of those who have sought to explain many optical anomalies in crystallized minerals by the theory of inner molecular tension due to secondary causes. The thorough examination of the Table Mountain analcite by Professor Klein, the results of which were published in the Neues Jahrbuch für Mineralogie, etc. (1884, I, 250), shows that the above statement is correct only for the larger crystals, while the smaller and most perfect ones agree entirely with the observations and conclusions of Ben-Saude. Renewed examination by us upon minute and carefully-selected crystals fully confirms this testimony.

Professor Klein also subjected our material to investigation in a direction recently followed by him in regard to many minerals with eminent success, particularly in the cases of boracite[11] and leucite.[12] By means of an apparatus devised for the purpose the effect of heat upon the optical properties of a given mineral can be observed under the microscope. The application of this method of research to the Table Mountain analcite enables Professor Klein to state that in sections parallel to $\infty O \infty$ and ∞O the doubly refractive action of the various segments into which the crystal is divided becomes less and less, and finally disappears entirely, leaving an isotropic field. By thin sections this change is effected rapidly, while in the thicker ones it is retarded, and in some cases was not wholly successful. These investigations seem to demonstrate clearly that analcite is a regular mineral, whose anomalous optical properties are due to molecular disturbances produced by a decrease in temperature from that prevailing at the time of formation of the mineral.

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[9] "Ueber den Analcim." Neues Jahrbuch für Mineralogie, etc., 1882, I, 41.

[10] Am. Jour. Sci., III, XXIII, p. 452, 1882.

[11] Neues Jahrbuch für Mineralogie, etc., 1882, I, 235.

[12] Ibid., 1884, II, 49.

CHEMICAL COMPOSITION.—Analyses of crystals, apparently pure, which were, however, not examined microscopically, gave as follows:

	XIV.	XV.
SiO_2	55.82	55.80
Al_2O_3	22.42	22.45
Na_2O	13.48	13.45
H_2O	8.38	8.35
(W. F. Hillebrand.)	100.10	100.05

Oxygen ratios:

$$
\begin{array}{lllll}
 & Na_2O & : Al_2O_3 & : SiO_2 & : H_2O \\
XIV. & 1 & : 3.03 & : 8.56 & : 2.14 \\
XV. & 1 & : 3.04 & : 8.57 & : 2.14
\end{array}
$$

The excess in silica and water is most probably due to presence of hydrated silica.

APOPHYLLITE.

GENERAL DESCRIPTION.—This mineral occurs in well-developed crystals of prismatic habit with ∞P∞ and P predominating, while 0P is in most cases quite subordinate or wanting entirely. The larger crystals which are occasionally half an inch in diameter, are often of a greenish tinge, sometimes quite pronounced, and possess more or less uneven surfaces produced by a repetition of the crystal faces, so that the termination is made up of a large number of small pyramids.

The prismatic surfaces are roughened by depressions or elevations bounded by prism and pyramid planes. This feature is very prominent in all large crystals, while the smaller ones are in contrast sharp and clear with smooth, brilliant faces. Especially noticeable on these small and clear crystals, though not peculiar to them, is a replacement of the pole edge of the pyramid by a small re-entering angle formed by pyramid faces. This angle is nowhere prominent, yet may be easily identified on all clear crystals, both large and small. No corresponding irregularity of any kind could be detected on the dimetric prism of these crystals.

As a rule the largest crystals occur in the small cavities, and their growth has been more or less hemmed by the walls, while the more perfect crystals are present in the large cavities, and are usually small and numerous.

OPTICAL PROPERTIES.—Apophyllite is another of the group of minerals exhibiting in many cases an optical behavior not in accordance with the outward symmetry, and the mineral from Table Mountain shows this anomalous action in typical form. The thorough investigation of such minerals having become within the past few years a work for the specialist, with appliances not at our disposal, we shall confine ourselves to a simple statement of observed facts. We are able, however, to refer to the published results obtained by Professor Klein from an examination of material from Table Mountain. Unfortunately but a few small crystals of this locality are suitable for such study, owing to the irregularities of form common to the larger ones, so that a satisfactory suite of specimens could not be placed at Professor Klein's disposal. His results are contained in the same article with those upon analcite.[13]

The mere observation of the optical anomalies of apophyllite is no difficult matter, provided good crystals are available, for the easily-obtained sections parallel to the perfect basal cleavage planes are most suitable for the purpose. It is, however, a significant fact that only the most perfect and symmetrically developed crystals exhibit the peculiar action in sufficiently simple form to permit a satisfactory description. With all apparent, and sometimes, it must be confessed, without visible irregularities in form, there appear variations and distortions of the more regular action about to be described.

The Table Mountain apophyllite crystals are bounded by ∞ P ∞ and P with 0 P as a frequent addition. If a regular crystal of this form be divided into a number of sections parallel to the basal cleavage plane, there will be small ones of square outline, situated in the pyramid near the apex; larger ones of octagonal form through the intersection of both pryamid and prism; and still lower, square ones again from the prism alone. Such sections, ground to the desired thinness and mounted in Canada balsam, show the following peculiarities when examined in parallel polarized light. Unless otherwise stated the examination takes place between crossed nicols, and the position in which the diagonals of the pyramidal section are parallel to the planes of vibration in the nicols is designated as position A, that produced by revolving the crystal section through 45°, as position B.

Figs. 4, 5, and 6, represent the relation in a crystal examined and described by Professor Klein,[14] all of them in position A. Fig. 4 illustrates the appearance in a section near the apex of a crystal having 0 P and showing the small re-entering angles above mentioned. In the centre is a dark field, whose outlines are only approximately parallel to those of the pyramid. The outer zone is then divided in segments based upon the four sides, the opposite pairs having the same optical orientation. Fig. 5 represents the division in the octagonal section cutting ∞ P ∞ and P. The central field is here much smaller and the segments upon P consequently larger. Based upon ∞ P ∞ are low triangular spaces of still different optical action. Fig. 6 shows the relations in a section of the same crystal taken in the prism. The central field is here very small, while those areas corresponding to the outlines of ∞ P ∞ have increased very markedly. The optical behavior of these divisions in position A is usually as follows: The central field is nearly or quite dark, the sectors based on outlines of P are light and equal, while those upon $\infty P \infty$ are not homogeneous in action. The areas based upon P are optically biaxial, the plane of the axes lying normal to the outline of P adjoining. When a gypsum plate producing red light of higher order is inserted, and so situated that the lesser axis of elasticity runs from the upper left-hand to the lower right-hand quadrant, the blank sectors appear yellow, the dotted ones blue, while the inner field has more or less perfectly the red color of the outer field of vision. The sectors based upon $\infty P \infty$ are usually variegated in color, red, blue, or yellow, as will be described further on. In position B the whole becomes dark except the irregular sectors adjacent to $\infty P \infty$.

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[13] Neues Jahrbuch für Mineralogie, etc., 1884, I, 253.

[14] These figures taken from the cited article.

The statements of Professor Klein are chiefly directed to show that the optical properties observed are, to a very large degree, dependent upon the crystal faces developed. Thus the crystal whose sections are figured had a well-developed basal plane, to which fact is attributed the presence of the central field, while the decrease in size, as the sections are taken deeper in the crystal, corresponds to the distance from 0 P. He states that in a crystal without a basal plane the central field is wanting. The appearance of the prism $\infty P \infty$ as a boundary of a section is accompanied by the appearance of the low triangular spaces of irregular optical behavior. The biaxial fields seem definitely related to the outlines of P.

The examination of several crystals with reference to this relationship between outer form and optical action has shown us that any generalization with regard to 0 P and the central field is impracticable. In several crystals showing no base at all the dark central field is present, in one case being large near the apex and very small in the prism; in another case the reverse; also in crystals with 0 P developed this field is sometimes smallest near that plane, and again it does not vary materially in size from the pyramid to the prism. In no case, however, has the prism $\infty P \infty$ appeared as a boundary of a section, without an adjacent field in which the action is often complex, the complexity increasing as the section is taken lower in the crystal. No sector in this position has ever been seen independent of the development of $\infty P \infty$.

The figures of Professor Klein are intended to illustrate the most regular action observed, and it is quite natural to assume that this simple relation of optically different parts is largely dependent upon the regularity in the development of the crystal form. The deviations from this simple relation and action of individual parts have never been fully described, but in the series of sections we have examined these variations are very numerous and seem quite as important in considering the cause of the optical phenomena as the more regular condition occasionally seen.

The central core is very variable in form. Within a given crystal it often changes perceptibly from section to section either in size or in outline. As has been stated, it may be largest near the apex of the crystal (whether $0P$ is developed or not) and steadily decrease in size downwards, or its apex may be in that of the pyramid, and in some cases it runs as an inner prism through the whole observed part of the crystal. Its section is but rarely square, although rectangular in many cases, and this variation has no observable relation with the prominence of adjacent pyramid faces. The more perfectly rectangular its outline the sharper its boundaries are, and the more homogeneous its optical action. Variations from the rectangle are produced by broken side-lines, by the deviation of its angles from 90°, and by an increase in size until it can no longer be inscribed within the prism $\infty P \infty$. With all such irregularities are combined disturbances in the optical action of the centre. In the simpler instances, by position A the field is not wholly dark and several faint black crosses are seen whose arms are parallel to the diagonals of the pyramid, and revolve with the section, disappearing more or less completely in position B. These arms rarely cross each other at exactly 90°, and especially where the side lines of the rectangle are broken the field is divided into numerous irregular areas, each having by position A a black cross whose arms may join at any angle. These revolve with the section and either disappear or become less distinct by position B. In one section the optical division is quite regular, in that by position A the field is composed of a mosaic of light and dark squares or rectangular blocks, whose sides are parallel to the outlines of the prism $\infty P \infty$. In position B the same structure is visible with the dark squares as the light ones. The lighter areas are very faint and shade off into the darker ones. With the insertion of the gypsum plate the place of the black cross is sometimes indicated by bushy indistinct blue and yellow arms, normal respectively to the adjacent blue and yellow segments on the outlines of P. In two or three cases one side of the central field is absent, and there is a gradual shading from the adjoining sector into the area of the centre. The opposite side of the field is very sharp and clear in such instances. By using the gypsum plate the change is very distinct, from the normal red next to the sharp outline, by transition shades out to the distinct yellow or blue of the sector.

The segments based upon P are much less subject to variation than the central field. They are always present and usually prominent. Normally they appear equally light in position A, but opposite pairs differ in intensity upon a slight revolution, and are wholly dark in position B. On insertion of the gypsum plate, in position A, one pair appears blue, the other orange-yellow. In regular crystals the dark lines which separate them run from the angles of the pyramid, or normal to $\infty P \infty$ if its faces are developed, to the angles of the central field, as in Figs. 4, 5, and 6. If the inner field is not regular, these lines must bend to meet the angles, and in fact they are often wholly irregular curved or broken lines, neither normal to each other nor to the outline of $\infty P \infty$. An optical variation of these segments is frequent, in that the outer portions or a broad band through the centre, parallel to the outline of P, is much lighter than that portion near the central field. If the gypsum plate is inserted the color of the lighter parts is purer blue or yellow, and shades off into reddish hues toward the red centre. In position A indistinct dark figures are sometimes seen, and these usually spring from a point on the surface or from the angles of the central field. Fissures when present commonly furnish a number of centres for such disturbances.

Finally, the areas based upon ∞ P ∞ are quite variable both in form and behavior. They are sometimes very low, perfect triangles, and in such cases their action is often simple. In position A they are dark, in B light. With the gypsum plate inserted they are red in position A, while in B opposite pairs are respectively blue or yellow, as with the pyramidal segments in the former position. When complex they consist chiefly of laminæ parallel to ∞ P ∞. In position B, with gypsum plate, a part of these laminæ appear red, the remainder blue or yellow.

The simple recital of the optical variations observed seems sufficient to deter any one from an attempt to explain the anomalous action of apophyllite on a theory of complex twinning. The insensible gradations and shadings between all structures and optical conditions seen, are much more characteristic of the phenomena due to unequal tension or pressure in glass and colloidal substances, than of any complex twinning definitely known in a mineral.

CHEMICAL COMPOSITION.—In chemical composition this apophyllite is quite normal, the fresh substance yielding the following:

	XVI.
SiO_2	51.89
Al_2O_3	1.54
Fe_2O_3	0.13
CaO	24.51
K_2O	3.81
Na_2O	0.59
H_2O	16.52
F	1.70
	100.69
O for F	0.72
	99.97

(W. F. Hillebrand.)

Considering all potassium and sodium as combined with fluorine, the following oxygen ratio is afforded:

$$RO : SiO_2 : H_2O$$
$$1 : 3.95 \ : 2.10$$

The theoretical ratio 1:4:2 would be still nearer approached were it not for a probable slight loss of silica and excess of water, scarcely to be avoided in analyses of silicates containing fluorine. The Fe_2O_3 is undoubtedly owing to minute particles of limonite which could not be completely removed. The Al_2O_3 is much higher than in most analyses, and the condition in which it is present seems undeterminable.

ALTERATION.—The Table Mountain apophyllite is frequently subject to alteration in a peculiar manner, which is, so far as we can ascertain, different from anything previously observed for that mineral. By this alteration a pearly-white, very finely-foliate substance is produced in the basal cleavage fissures of the apophyllite. The decomposition begins at the surface and progresses inward, the flakes of the newly-formed substance lying parallel to the cleavage planes. Some crystals which are outwardly snowy white, show perfectly fresh substance within. When the outer surface of an altered crystal is dull the resemblance to albine is marked, but on fracturing such a crystal the distinct foliation and lustre show the different nature of this substance.

As more or less apophyllite is usually mixed with the alteration product it was quite difficult to ascertain its chemical composition. Material apparently very pure was finally obtained from the specimen in which the decomposition was most advanced, by treatment in the following manner: The finely-powdered substance was stirred up in water, and the finer portions were poured off from the heavier impurities; the material suspended in the water was allowed to settle, the clear liquid was decanted, and the residue evaporated, accidentally *quite* to dryness. It having been found that the air-dried material lost several per cent. of water over sulphuric acid, it was certain that some loss had been occasioned by drying on the bath; hence the drying was completed at 100° C., and the following analysis was then made:

	XVII.
SiO_2	67.96
Al_2O_3	8.48
Fe_2O_3	1.04
CaO	5.47
MgO	0.53
K_2O	1.23
Na_2O*	0.74
H_2O	14.55
F	none
	100.00
(W. F. Hillebrand.)	

* By difference.

The Fe_2O_3 comes from certain reddish flakes which could not be separated. The H_2O is, from reasons above given, much too low, and the other figures are consequently too high.

Neglecting Fe_2O_3 and H_2O the following oxygen ratio is obtained:

$$\begin{array}{ccccc} RO & : & Al_2O_3 & : & SiO_2 \\ 1 & : & 1.86 & : & 16.66 \end{array}$$

from which no satisfactory formula is deducible.

It is plain that this alteration product has nothing in common with albine except the color, Knop [15] having proved, for many cases at least, that the latter substance is chiefly calcite.

MESOLITE.

GENERAL DESCRIPTION.—Mesolite is the last of the minerals deposited at the locality on North Table Mountain where all of the species thus far described occur so often together that their order of succession is plain. The mineral appears uniformly in masses composed of exceedingly delicate needles loosely grouped together, very much like the spicules of a fine sponge. Such light aggregates frequently fill the smaller cavities entirely. In the larger ones the bases of the rounded bunches, 1 to 2 inches in diameter, often touch each other. The very latest deposition, the finishing touch so to speak, is a thin film coating the whole mass. This is sometimes a continuous membrane, and in other cases more like a thick cobweb. The exquisite delicacy of some of these films is quite wonderful. In rare cases bunches on the upper and lower walls of a cavity are united by such a membrane. Single needles are clear, but the aggregate appears pure white.

As was mentioned under thomsonite, the loose aggregates of the second generation of that mineral seem specially suited to attract the deposition of mesolite.

None of the mesolite needles are large enough to allow any determination of their crystal form, even under the microscope at a high power. They seem simply like very fine transparent hairs.

CHEMICAL COMPOSITION.—The identification as mesolite rests upon the following chemical analysis:

	XVIII.			Mean.
	a.	*b.*	*c*	
SiO_2	46.14	46.02	46.33	46.17
Al_2O_3	26.88	26.87	....	26.88
CaO	8.77	... ...	.... ..	8.77
Na_2O	6.19	....	....	6.19
H_2O	12.17	12.17	12.13	12.16
(W. F. Hillebrand.)	100.15	... .	....	100.17

Oxygen ratio:

$$\begin{array}{cccc} RO & : R_2O_3 & : SiO_2 & : H_2O \\ 1 & : 3.08 & : 6.00 & : 2.63 \end{array}$$

If mesolite be considered as a mixture of the isomorphous silicates contained in scolecite ($CaAl_2Si_3O_{10}+3$ aq) and natrolite ($Na_2Al_2Si_3O_{10}+2$ aq), the present occurrence would answer very nearly to the requirements of the combination of 2 of scolecite + 1 of natrolite, the percentage of which would be: SiO_2 46.32, Al_2O_3 26.40, CaO 9.61, Na_2O 5.32, H_2O 12.35=100.00.

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[15] In Blum, Die Pseudomorphosen, etc.; Dritter Nachtrag, 1863, p. 41.

NATROLITE.

DESCRIPTON AND ANALYSIS.—Natrolite occurs much less abundantly than any of the species thus far described, and seems to be restricted locally to the northern part of South Table Mountain. It usually appears in delicate prisms sparingly deposited upon analcite or associated with that mineral in fissures. It has also been observed upon yellow calcite, chabazite, and thomsonite.

The crystals show only ∞ P and P; they extinguish light exactly parallel to the prism, and are therefore of the normal rhombic type. The microscope shows many crystals to be partially coated with calcite, which explains the presence of $CaCO_3$ in the following analysis of the needles:

	XIX.
SiO_2	43.66
Al_2O_3	24.89
CaO	4.87
Na_2O	14.66
H_2O	*8.09
CO_2	†3.83
	100.00
(W. F. Hillebrand.)	

*By difference. †Calculated for total CaO.

There being much less than half a gram of material at disposal for analysis, no attempt at a direct water determination was made. On treating with acid there was a strong effervescence of CO_2; therefore in calculating the following oxygen ratio the CaO was assumed to be present entirely as $CaCO_3$.

Oxygen ratio:

$$Na_2O : Al_2O_3 : SiO_2 : H_2O$$
$$0.98 : 3.02 : 6.00 : 1.85$$

A study of the ratio time thus obtained, however, renders it probable that a small part of the CaO was combined with silica, in which case the CO_2 would be less and the H_2O consequently higher, bringing the ratio still nearer to the theoretical 1 : 3 : 6 : 2.

SCOLECITE.

DESCRIPTION AND ANALYSIS.—Scolecite occurs sparingly in a zone just above that containing a great number of the zeolites. It appears in small spheres or segments of spheres with a radiate structure, and greatly resembles thomsonite, though easily distinguished by the brilliant white color and satin-like lustre. Toward the centre of the aggregates there is often a greenish color.

The mineral only occurs in very small cavities, which are often entirely filled by it and seldom contain any other zeolite. Minute tablets of brown mica which are coated, as are the walls of the cavity, by a lavender-colored material, usually appear as the only associates of the scolecite. It occurs also in some cases with the next species to be described. Chabazite and thomsonite may occur in larger cavities directly adjacent to smaller ones containing scolecite, but they have never been found with the latter.

The mineral gelatinizes on treatment with hydrochloric acid and was found to have the following composition:

	XX.
SiO_2	46.03
Al_2O_3	25.28
Fe_2O_3	0.27
CaO	12.77
Na_2O	1.04
K_2O	0.13
H_2O	*14.48
	100.00
(W. F. Hillebrand.)	

* Difference.

No attempt at a direct water determination was made, owing to the small amount of pure material available.

Oxygen ratio:

$$RO : Al_2O_3 : SiO_2 : H_2O$$
$$1 : 3.02 : 6.23 : 3.26$$

It was impossible to free the mineral entirely from attached limonite and an insoluble silicate, which probably accounts for the high values for SiO_2 and H_2O in the oxygen ratio. The agreement with the theoretical ratio 1 : 3 : 6 : 3, is, in any case, close enough to establish the identity of the mineral as scolecite.

LEVYNITE.

GENERAL DESCRIPTION.—To the species levynite is referred a mineral occurring very sparingly in small cavities side by side with those containing scolecite, although the two have never been observed together. When but partially filling the cavity, white or colorless tabular crystals are developed, which resemble very closely the form usually given as characteristic of levynite. Referring to the figures of Dana or Naumann-Zirkel, and adopting the ground form of the latter, the Table Mountain crystals are formed of twins of interpenetration producing hexagonal tablets with 0 R and R as the chief faces, the reentering angle formed by $-\frac{1}{2}R$ being seldom distinct. R is always striated, often coarsely, parallel to the combination edge with $-\frac{1}{2}R$.

The faces of R and 0 R are not smooth enough to allow of good reflections, hence the following measurements are not very exact, although sufficiently so to prove the identity in crystal form with levynite:

	Measured.*	Theoretical.
$R \wedge R$ (hor.)	125° 10′	125° 14′
$0R \wedge R$	117° 38′	117° 29′
$R \wedge -\frac{1}{2}R$	130° 22′	129° 45′

*Average.

The crystals are attached by an edge, about half of the full crystal being developed free. They are extremely brittle, and fracture very easily at right angles to the horizontal edge of R, *i. e.*, parallel to ∞ P 2, so that material suitable for optical observation could not be obtained.

Associated with the levynite in some cavities or appearing independently in adjoining ones, is a fibrous mineral, dull white in color and never showing crystal faces. As seen below it is practically identical with the levynite in composition, although so different in formal development. It cannot be referred to any definite species from present data.

CHEMICAL COMPOSITION.—Analysis of the pure crystals of levynite gave XXI, while the allied substance has the composition XXII:

	XXI.	XXII.
SiO_2	46.76	46.97
Al_2O_3	21.91	22.39
CaO	11.12	10.85
K_2O	0.21	1.17
Na_2O	1.34	0.79
H_2O	18.65	18.03
	99.99	100.20
(W. F. Hillebrand.)		

Oxygen ratios:

$RO : R_2O_3 : SiO_2 : H_2O$

XXI. 1 : 2.90 : 7.01 : 4.66

XXII. 1 : 3.01 : 7.15 : 4.58

The water lost in drying has been included in the oxygen ratios, for the reasons given under laumontite. The ratios for dried material are:

XXI. 1 : 2.90 : 7.01 : 4.03

XXII. 1 : 3.01 : 7.15 : 3.94

OTHER MINERALS.

BOLE.

DESCRIPTION AND ANALYSIS.—In many irregular cavities in the scoriaceous crust of the lower sheet, and especially noticeable at about the centre of the northern face of South Table Mountain, is a dark brown clay which probably comes under the above head. It is very dense and apparently homogeneous, and has the peculiar fracture characteristic of such masses. Placed in water it falls apart without decrepitation. It is often associated intimately with a brown massive calcite, and in other cases it alone fills cavities completely. Two specimens, one of a light (XXIV), the other of a dark brown color (XXIII), were subjected to analysis.

	XXIII.	XXIV.
SiO_2	42.63	46.17
Al_2O_3	18.76	22.03
Fe_2O_3	11.88	4.64
CaO	2.59	2.30
MgO	3.39	2.42
K_2O	0.35	*2.06
Na_2O	0.24	
H_2O	20.21	20.38
	100.05	100.00
(W. F. Hillebrand.)		

*By difference.

From these results no satisfactory ratio or formula can be deduced. They probably represent mixtures of different hydrous silicates.

CALCITE.

Occurrence and Description.—The carbonate of calcium has had three periods of deposition in the basaltic cavities of Table Mountain, two as calcite and one as aragonite. In the form of wine-yellow crystals it preceded even chabazite, being in all observed cases deposited directly on the basalt and coated usually by chabazite or thomsonite. It is rarely found in those cavities to which water has had access through fissures, having been dissolved. The second deposit of calcite came after apophyllite. These crystals are colorless or slightly straw-yellow, and the form of both varieties is commonly that of a sharp scalenohedron terminated by a low rhombohedron.

The aragonite is present only as a snow-white incrustation, apparently with a special tendency to deposition upon chabazite, though often noticed upon apophyllite and thomsonite. It was next to the last mineral deposited, only mesolite having been observed upon it.

The brown calcite mentioned as associated with bole is never present in the zeolitic cavities.

II.—MINERALS FROM THE NEIGHBORHOOD OF PIKE'S PEAK.

By WHITMAN CROSS and W. F. HILLEBRAND.

GENERAL.

The name of Pike's Peak has become well known the world over in connection with the large and perfect crystals of Amazon stone (microcline) which have found their way into almost every mineral collection of importance, and yet the stranger who ascends the mountain from Manitou may see no sign of that or of any other of the numerous species accredited in a general way to the region. It may be well, therefore, to preface this description with a few remarks concerning the mode of occurrence and the distribution of the Pike's Peak minerals.

The mountain proper rises to a height of 14,147 feet, and is surrounded by many lesser peaks which reach 10,000 feet. The same coarse reddish granite which forms the greater part of all these points extends in a northerly direction for at least 35 miles. Owing to a lack of gold and silver bearing ores the granitic formation has not been thoroughly explored, the region is uninhabited, excepting on certain routes of travel, and the great majority of the mountains and streams are unnamed. Hence it is that minerals found in many remote spots are afterwards labelled simply as from Pike's Peak. For many of the species the inaccuracy is unimportant, as throughout the entire granitic area some of them are surely to be found upon search.

LIST OF SPECIES KNOWN.—Up to the year 1882 the following minerals had been identified with certainty, viz.: Microcline, albite, biotite, muscovite, quartz (smoky and clear), fluorite, columbite, göthite, hematite and limonite (pseudomorph after siderite), arfvedsonite, astrophyllite, zircon, bastnäsite, and tysonite. The species described in this article have been identified by us since that time, viz: topaz, phenacite, kaolinite, cryolite, pachnolite, thomsenolite, gearksutite, ralstonite (?), prosopite, and elpasolite.

Another series of minerals now in the course of investigation embraces several salts of cerium, yttrium, etc., belonging to species not as yet fully determined, although xenotime and yttrotantalite are probably present. Cassiterite also occurs in small quantity. (See p. 74.)

MODE OF OCCURRENCE.—The reddish granite of the region belongs to a type common in the Colorado range of the Rocky Mountains, and is supposed to be a part of the Archæan formation. It consists of a largely predominant reddish feldspar, to which are added brilliant black biotite and quartz, the latter subordinate, and occurring in small grains. The feldspar consists largely of an intergrowth of orthoclase and albite, somewhat after the manner of perthite.

Throughout the granite body, though much more abundant in some places than in others, are drusy cavities or "pockets" of very variable size, and often distorted by movements of the rock mass. Lining these druses, or entirely filling them in some cases, are crystals of feldspar and smoky quartz, in the first degree, with fluorite, topaz, phenacite, zircon, göthite, hematite, and limonite, as more or less constant companions.

The granite disintegrates rapidly through the action of the weather into a coarse, gravel-like mass, and many of the mountain slopes are covered by such material, with solid rock appearing here and there. On finding fragments of crystal in the *débris* the prospector for minerals, with pick and shovel in hand, endeavors to find the original cavity from which the fragments came. One of these druses has been known to yield more than a ton of crystallized specimens of Amazon stone, smoky quartz, etc.

Vein-like masses, composed chiefly of white quartz and reddish microcline, are also locally abundant, and in these are sometimes found small masses of cryolite and its alteration products, with zircon, astrophyllite, and columbite as observed associates.

CRYOLITE.

LOCALITY.—The point at which cryolite and its alteration products have been found is at the northeastern base of Saint Peter's Dome, a minor peak due west of Cheyenne Mountain and near the toll-road from Colorado Springs to the Seven Lakes, at the southern base of Pike's Peak. The spot lies nearly on the southeastern border of the extensive region within which Amazon stone and its associates occur, and may be thus considered within the "Pike's Peak region," although several miles distant from the mountain proper. The fluorides were first shown in a prospect shaft and in a neighboring tunnel, but visits made to the locality since the first publication have proven the presence of cryolite masses in several of the small irregular veins north and west of Saint Peter's Dome.

OCCURRENCE AND ASSOCIATION.—The manner of occurrence and the relationship of the fluoride masses can now be stated much more clearly than was possible in our first notice. Cryolite, in the massive form to be described, was deposited in the veins of secretion which are so abundant in the granite country rock, in small but pure and homogeneous masses. Some of these veins have certainly had two periods of secretion, as is shown in the Eureka tunnel, Saint Peter's Dome. This tunnel penetrates for about 200 feet an irregular mass, consisting largely of white quartz and reddish microcline. The greater part of the quartz is the common white vein material containing no included minerals, but a portion of it, appearing in sharply defined angular blocks, is full of the transparent zircon to be hereafter described. Small particles of microcline are also disseminated through this quartz, while in the body of the vein it presents huge individuals, sometimes several feet in diameter. An examination of the tunnel walls shows here and there faces of pure massive fluorides 5 or 6 feet across and sharply defined against both pure and zircon-bearing quartz, the spaces filled being very irregular and angular. No contemporaneous minerals of importance accompany the zircon and cryolite in this vein.

The purity or homogeneity of the white quartz, zircon-bearing quartz, and fluoride masses, together with their irregular forms, seems to indicate different periods of development, and it seems further probable that a time of disturbance, in which the original quartz and feldspar vein was much fractured, produced the irregular spaces subsequently filled by different deposition. The cryolite may have been formed here during the time in which fluorite and topaz were deposited in the cavities of the region to the northwest.

The only mineral observed to be undoubtedly contemporaneous with the cryolite is columbite, which has been seen in small crystals embedded directly in fresh cryolite. At one place astrophyllite blades penetrate cryolite, but these are implanted directly upon the granite wall, and are probably an earlier formation, as are the zircon crystals at their base, and impregnating the granite itself. In the immediate neighborhood arfvedsonite and astrophyllite are quite abundant, both occurring most frequently embedded in white massive quartz. The original locality of tysonite and bastnäsite is not far from Saint Peter's Dome, but little is known to us concerning the manner of occurrence of these minerals.

PURELY SCIENTIFIC VALUE OF THE DISCOVERY.—As numerous inquiries concerning the probable commercial value of this new cryolite locality have been received since the published description, it may be well to emphasize the conclusion which is clearly suggested by the description of the occurrence of the mineral. All the cryolite as yet known occurs in the form of subordinate masses in the veins of secretion which appear here and there throughout the granitic formation, and there is no reason to suppose that masses of economic importance can occur in the region.

RECENT LITERATURE OF CRYOLITE AND ITS ALTERATION PRODUCTS.—The minerals of this group, of which so little was known a few years ago, are now among the best known. As most of the recent publications are of direct interest to us in describing the material of the new find, a brief mention of the leading articles is in place.

The earliest contribution to be mentioned is that of Prof. P. Groth, then in Strassburg, who instituted a careful investigation of cryolite and its alteration products, several of which had received names without satisfactory proof of their homogeneity, while more or less doubt was justifiable in regard to the chemical composition of all of them. Similar rare minerals of other occurrence were also studied. The purely mineralogical part of this investigation was conducted by Professor Groth personally, while material selected by him was subjected to chemical analysis by Dr. J. Brandl, in Munich. To the papers by Messrs. Groth[16] and Brandl[17] we shall refer frequently in the course of the following description. Owing to better material we are able to supplement in some particulars the results of these gentlemen, and in but a a single case, namely, in regard to the composition of pachnolite, is there any discrepancy between our conclusions and theirs.

Concerning the crystallography of the group, Krenner[18] and Des Cloizeaux[19] have made important contributions while the laws of twining in massive cryolite have been investigated by Mügge.[20]

General Description.—The pure cryolite appears in massive aggregates of large individuals, quite like that from Greenland. The three prominent cleavage surfaces are often continuous for two or three inches, indicating the size of the individuals present. A delicate pink or even decidedly rosy hue is characteristic of the freshest substance found, but the greater part is either of a faint greenish tinge or dull white, and none so far obtained has the snowy whiteness or the clearness of the Greenland mineral. The color disappears on heating, leaving the cryolite pure white.

The three marked cleavage directions are situated nearly at right angles to each other and one seems slightly more perfect than the other. A parting parallel to these planes is by no means so easily effected as one would expect from the distinctness with which they are seen, a fact explained by the complicated polysynthetic structure to be described.

Twin Structure.—As no crystals of cryolite have been found in this locality, the study of the complicated twin structure exhibited by the massive material is no easy matter. The recent investigations of

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[16] P. Groth. "Beiträge zur Kenntniss der natürlichen Fluorverbindungen," Zeitschrift für Krystallographie, VII, pp. 375–388 and 457–493, 1883.

[17] J. Brandl. Sitzungsbericht der königl-bayr. Akademie der Wissenschaften zu München, 1882, p. 118, and Annalen der Chemie, CCXIII, p. 1.

[18] J. A. Krenner. "Die grönländischen Minerale der Kryolith Gruppe." Budapest, 1883.

[19] A. Des Cloizeaux. "Nouvelles observations sur le type cristallin auquel doit être rapportée la cryolite." Bull Soc. Min. d. Fr., 1883.

[20] O. Mügge. "Über die Zwillingsbildung des Kryolith." Jahrbuch d. wiss. Anstalten zu Hamburg, 1883, p. 67.

Krenner, and especially those of Mügge upon the massive mineral from Greenland, have, however, done much to make the relations clear.

Dana[21] mentions ∞ P, Websky[22] 0 P and $\infty P \breve{\infty}$, and Krenner[23] ∞ P and ½ P as twinning planes identified upon crystals of cryolite. Mügge[24] seems to have identified ± ½ P as a twinning plane in the massive material, independently of Krenner's determination. In all the above-mentioned laws the axis of revolution is the normal to the twinning plane, which is usually the composition face. The polysynthetic development of various laws was briefly alluded to in the first notice of the Colorado cryolite, and the descriptions of Mügge show that a similar, although by no means equally complicated, structure exists in the Greenland mineral.

The well known pseudo-symmetry of cryolite is illustrated by the following values, taken from Krenner: $\beta = 89° 49'$; the prism angles are 88° 2′ and 91° 58′, the angles between 0 P and opposite prism faces are 90° 8′ and 89° 52′. The axes of elasticity are also situated in peculiar agreement with this symmetry, the bisectrix lying in the clinodiagonal section, inclined 43° 54′ to the vertical axis and 45° 55′ to the clino axis. It is to be noticed that by all the above-mentioned laws of twinning the planes of 0 P and ∞ P are brought in so nearly coincident positions that the deviations are unnoticeable upon the cleavage surfaces of the massive substance.

The examinations of Mügge were conducted upon thin sections lying in water, the index of refraction of the liquid being almost equal to that of cryolite. Our observations were made upon sections prepared in the usual manner. As none of them exhibit anything corresponding to the results obtained by Mügge on heating to a temperature of over 400° C., it is assumed that no change in the optical properties was produced by the temperature necessary in mounting these sections in balsam.

Although we cannot in the cleavage material distinguish with certainty between ∞ P and 0 P, or between the positive and negative quadrants, still, if from a given cube, sections be prepared parallel to each of the three cleavage faces, we should be able to observe the relations of all twinning laws seen to each other and to a ground form which can be assumed. For a clear distinction of all the individual parts it is necessary to examine the thin sections between crossed nicols and with an inserted gypsum plate giving the field of vision a red color of the higher order. As nearly all the twinned parts are symmetrically related to ∞ P or 0 P, the first position in which their relations can be seen to advantage is secured by placing the cleavage lines in each section ± to the principal sections of the crossed nicols. This position is hereafter designated as position I. It is evident that the extinction in the basal section takes place parallel to the diagonals of the prism, as indicated by the cleavage lines, *i. e.*, about 45° from each. The theoretical extinction parallel to a face of ∞P is 31° 15′ from the vertical axis (Groth); which direction lies parallel to one set of cleavage lines.

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[21] System of Mineralogy, 5th ed., p. 127.

[22] Neues Jahrbuch für Mineralogie, etc., 1867, p. 810.

[23] *Loc. cit.*

[24] *Loc. cit.*

The various laws of twinning observed will now be taken up and the resulting structure parallel to each of the cleavage faces described.

Law a.—Twinning plane and composition face ∞P, axis the normal upon it.

One of the three sections shows a fine banded structure parallel to one set of cleavage lines; this resembles plagioclase twinned according to the albite law, but the boundaries are less clearly defined. In position I alternate bands are blue, the remainder yellow; reversed colors are produced by a revolution of 90°; extinction occurs at about 31° from the twinning plane, right or left according to color. The second section shows no such banded structure, but extinction takes place at 31° from either cleavage system. The third section exhibits a banded structure with blue and yellow colors, but with nearly coincident extinction at 45° from the twinning line, which is parallel to one cleavage direction.

As experience shows this twinning to be always parallel to one pair of prism faces and there is evidently a definite relation between the other laws and the present, we will assume the left-hand front prism-face as the twinning plane, ∞P (*l*). The first section was therefore parallel to ∞P (*r*), the second to ∞P (*l*), and the third to $0 P$. This assumption is made in all subsequent discussion, so that the relations of the different laws may be correctly expressed.

The laminæ are sometimes broad, but more frequently narrow, measuring 0.01 to 0.10^{mm} in thickness. It is therefore difficult to prepare a section so nearly parallel to ∞P (*l*) that it shall not cut obliquely several of the laminæ, producing a broad irregular banding, as represented in Fig. 7. The four vertical bands with irregular boundaries are alternately blue or yellow in position I, and extinguish at 31° right or left.

Law b.—Twinning plane and composition face $\frac{1}{2} P$ (*r*), axis the normal upon it.

Sections parallel to ∞P (*r*) usually show in each lamina produced by the first law a structure illustrated by the lower left-hand portion of Fig. 8. The parts of new orientation are represented by the small rectangular or graphic forms lying parallel to the diagonals of the square, right or left as the case may be, and however zigzag the shape the bounding lines are almost always parallel to the diagonals mentioned. These forms are apparently identical with those described by Mügge as twinned parallel to $\pm \frac{1}{2} P$, and they appear in the other two sections in a manner agreeing with this supposition. In Fig. 7 they are represented by the smaller horizontal lamellæ which do not cross the boundaries of the broad bands, and in Fig. 9 by the vertical lamellæ included in the larger ones. They are therefore cut by the plane ∞P (*r*) nearly or quite at right angles, and their inclination is that of the plane ±½ P, according to which they are intergrown.

The explanation above given is, however, insufficient, as there are particles of three distinct optical orientations among these formally indistinguishable portions. If a lamina cut parallel to ∞ P (*r*) be placed in position I, and then shows a blue color, the visible included parts of the form in question will appear yellow. On revolving the lamina 31°, to its position of extinction, it is found that some of those diagonally situated particles have the same extinction as the lamina containing them, while the others become still brighter yellow and are found to extinguish simultaneously with the adjacent yellow lamina. On moving the section out of position I diagonal parts of the third orientation appear. These were blue in position I, but do not extinguish with the substance surrounding them; on the contrary, they correspond in this particular with the neighboring yellow lamina. It is impossible to definitely determine the laws according to which the substances are twinned, but in Fig. 10 the observed relations are explained in one way. The larger arrows indicate the normal directions of extinction parallel to ∞ P (*r*), with reference to the vertical axis. The area *x* represents the position of the corresponding directions of extinction in a lamella twinned parallel to the upper right-hand face of the positive hemipyramid, ½ P (*r*). This will extinguish at 31° to the right from the vertical axis, while corresponding very nearly in color with the inclosing substance in position I. This is considered the equivalent of the law identified by Krenner. The lamella *y* is related to *x* as if twinned according to law *a*, and thus will exhibit parallel extinction with the inclosing substance but the opposite color in position I. The part *z* corresponds in color and extinction to the adjacent lamina, twinned after law *a*, and intergrown parallel to ½ P (*r*) or — ½ P (*l*).

Careful study of a number of sections has failed to show any method of distinguishing between these various parts aside from their optical orientation. Now one, now another, seems to predominate, and often all three are to be seen in a single lamina.

The sections parallel to ∞ P (*l*) and 0 P cut these thin particles at an oblique angle, and their proper optical action is thus so obscured that they cannot be used to test the accuracy of the relation represented by Fig. 10.

Law c.—Twinning plane ∞ P ∞, axis the normal upon it, composition face ∞ P, or an irregular surface near it.

Sections parallel to 0 P never show a twinning plane running parallel to either pinacoid, and yet substance is found whose orientation corresponds to the requirements of the above law. This is shown upon 0 P by polysynthetic twin structure parallel to the second prism plane, ∞ P (*r*), the laminæ extinguishing at 45° and hence presenting 0 P. See Fig. 9.) This might be considered as twinning after the prism plane ∞ P (*r*) except that a corresponding structure upon ∞ P (*l*) does not appear. There is, it is true, a vertical lamellar twinning sometimes seen, but accompanied by the substances intergrown as described under law *b*. This is represented in Fig. 7, and is the natural result of law *c*, which brings ∞ P (r) with its twinning after laws *a* and *b* into parallel position with ∞ P (l), produces a crossing of the laminæ upon 0 P, and, lastly, brings ∞ P (l) parallel to ∞ P (r). This latter position is naturally seldom seen in sections, as the part thus twinned is usually a rather thin plate parallel to ∞ P (r), of the chief individual. In one case, however, a section parallel to ∞ P (r) which exhibits the usual complicated structure over the greater part, passes by an irregular indistinct line into substance of more simple action, like that represented for ∞ P (l) in Fig. 7, as if the slightly oblique section plane had cut into the plate twinned after this law *c*. Websky describes the composition face, in the case noticed by him, as irregular, although lying approximately parallel to ∞ P ∞.

Law d.—Twinning plane $\frac{1}{2}$ P (l), axis the normal upon it, composition face ∞ P (l), or an irregular surface near it.

By this law ∞ P (r) and 0 P are interchanged. It seems required to explain the appearance in the section parallel to ∞ P (r) of laminæ parallel to those of *a*, but with extinction of 45° (see Fig. 8), and the similar laminæ on 0 P with extinction of 31°, and including parts twinned after the law *b*. Upon ∞ P (l), the composition face, this law cannot be identified.

Law e.—Twinning plane $-\frac{1}{2}$ P (l), axis the normal upon it, composition face irregular.

This law seems required to account for certain relations frequently seen upon ∞ P (r) and ∞ P (l). Upon the former the usual structure of this face appears at right angles to its proper position, while upon ∞ P (l) horizontal bands may be seen which are polysynthetic, and give extinction at 45° from position I. This would be explained by the law above given, and is illustrated by Figs. 7 and 8.

Of the above laws the first seems to be identifiable in all portions not parallel to the twinning plane, and the second is nearly as persistent. Law *d* affects substance already twinned after laws *a* and *b*, while *c* and *e* produce a twinning of matter showing *a*, *b*, and *d*. Laws *c*, *d*, and *e* are thought to be justified, for however irregular their composition face, the position of the parts twinned after *a* and *b* is always a very definite and regular one with reference to corresponding parts in the primary individual.

Whether the prismatic twinning plane is right or left, it is clear that the planes of laws *b* and *e* and the composition face of *c* lie in the zone between the prismatic twinning plane and 0P, and that the plane of *d* is in the zone of 0P to the other prism plane.

No twinning parallel to 0P was noticed, unless a horizontal division of a few laminæ twinned after *a* be thus interpreted (Fig. 8).

CHEMICAL COMPOSITION.—For all analyses of this and the following minerals the greatest care was taken to have the purest of reagents. The fluorine was in all cases determined by the Wöhler-Fresenius method, with the slight modifications introduced by Brandl,[25] except that the iron plate instead of the oil-bath was used for heating. The sulphuric acid was obtained of the highest degree of concentration and purity by distillation from a platinum retort. The water was determined by absorption in a chloride of calcium tube, the mineral having been heated in a tube with either oxide of lead or carbonate of sodium, the results being the same whether one or the other was used.

The cryolite, of which the analysis is here given, possessed the specific gravity 2.972 at 24° C., was faintly pink in color, and contained as a visible impurity the oxide of iron represented in the analysis:

	XXV.
Fe_2O_3	0.40
Al	[26]12.81
Ca	0.28
Na	32.40
H_2O	0.30
F	[a]53.55
	99.74
(W. F. Hillebrand.)	

[a] As the mean of 53.35, 53.46, 53.55, and 53.85.

The presence of a slight amount of water indicates incipient alteration, but although purer and fresher material was subsequently obtained, a second analysis seems unnecessary.

ALTERATION OF CRYOLITE.—Although pure and fresh cryolite is common, the greater part of masses so near the surface is naturally changed. In the Eureka tunnel the surfaces seen upon the walls exhibit plainly the three cleavage directions of cryolite, especially when moistened. The material is chiefly massive pachnolite, however, as can be distinctly seen in thin sections, while fresh cryolite is still visible in small patches. Alteration of the cryolite proceeds in two ways, producing the same minerals in the end. By one process the principal cleavage fissures are utilized by the solutions which effect the change, and thin walls are formed of a white crystalline substance. The next step seems to be the bodily removal of the cryolite matter between these walls, leaving a network of partitions in the three directions of the chief cleavages of the original cryolite. These partitions or walls are lined by minute crystals. The second mode of alteration proceeds from the neighboring quartz and from the boundaries of the different crystalline individuals of the cryolite, the result being a compact crystalline mass of a faint bluish tinge. The material at hand illustrates the two processes and their products about equally well, and they are often combined.

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[25] Annalen der Chemie und Pharmacie, CCXIII, p. 1.

[26] If Al=27. In this and all subsequent analyses, percentages of aluminium are calculated with the assumption of 27 as its atomic weight.

A large part of the material in the Eureka tunnel is a massive mixture of indistinguishable compounds, probably derived from the alteration of pachnolite. Fluorite is one of the further products, but never appears prominently.

The small mass of fluorides struck in the incline near the Eureka tunnel is remarkable for the purity of a number of further products. Near the quartz and granite walls decomposition has progressed until a pure white substance has been formed, which, when dry, is a kaolin-like powder of extreme fineness. It resembles plaster of Paris when wet, as it invariably is in the vein. This is the gearksutite to be described further on. From this same small mass were obtained most of the specimens utilized in the determinations of the species whose consideration follows.

PACHNOLITE.

FROM THE THIN WALLS.—The microscopical examination of the walls and membranes produced by the first mode of alteration of the cryolite, shows them to be coated by many minute but perfect, colorless, and transparent prismatic crystals, which are usually placed at right angles to the central plane of the wall, though sometimes in an irregular manner. They reach a maximum length of 2^{mm} by a thickness of 0.2 to 0.4^{mm}. The crystals are occasionally yellow in color while retaining their transparency, the color being doubtless owing to some matter derived from the alteration of the astrophyllite which penetrates all such specimens. The crystallographical identification of these crystals with pachnolite is quite certain, for upon placing them in vertical position under the microscope the prism angles can readily be measured, and correspond closely to 81° 24′ and 98° 36′, the theoretical angles of pachnolite (see Groth, l. c., p. 463). The prism ∞P and base $0P$ are in all cases the chief faces, accompanied frequently by a hemi-orthodome and very rarely by a clinodome, both very slightly developed. The former is considered to be $-P\overline{\infty}$, from data given below. Pyramid faces have not been seen upon crystals of this growth. Although all detached crystals show, when examined in polarized light as lying upon a prism face, an oblique twinning plane in the prismatic zone,[27] still a projecting angle upon the base can but rarely be seen. The reflecting surfaces of the thinnest walls are composed of innumerable small facets of rhombic outline,—the basal planes of the very low prisms. In fragments from some of the thinnest walls, placed horizontally under the microscope and observed in polarized light, twinning parallel to the shorter (ortho-) diagonal can easily be seen. The crystals are usually quite equally bisected by the twinning line. The central portion of these walls is rather dull white, and probably represents the alteration product on cleavage planes of the original cryolite, while the crystals themselves were formed during or after the removal of the intermediate cryolite substance. Material from a network of thin walls covered by pachnolite crystals was subjected to chemical analysis, yielding the result under XXVII, p. 54.

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[27] Groth, *l. c.*, p. 464.

FROM THE BLUISH MASSIVE ALTERATION PRODUCT.—The pale bluish mass formed by the second mode of decomposition has, in great part, a regular crystalline structure produced by a more or less perfect intergrowth of pachnolite individuals in three directions approximately at right angles to each other. Nearly simultaneous reflection over the greater part of certain irregular surfaces make this relation plain. By the examination of such a surface with a lens one can usually identify a number of rhombic facets which are nearly or quite coincident in position with striated planes, the two corresponding to 0P and ∞P of different individuals. Such a structure is also illustrated by the crystals in the numerous small cavities occurring in the massive material.

These cavities are wholly of irregular shape and reach a maximum observed diameter of 3 to 4^{cm}. The crystals lining them are often very perfect, and are occasionally 2 to 3^{mm} in length, with a thickness of 1^{mm} or less. The study of these crystals proves that, as in the preceding case, most of them must be referred to pachnolite, although thomsenolite is sparingly present. These pachnolite crystals differ in habit from those already described in that the pyramid is usually prominent, being, however, in nearly every case truncated by the basal plane; in fact, crystals without 0P are very rare. The rhombic section of the prism is everywhere plain. Although every prism on being optically tested shows a twinning plane in the prismatic zone, the low projecting angle of 179° 20′ upon 0P can seldom be distinctly seen. Many crystals are somewhat extended parallel to one pair of prism faces. A hemi-orthodome of the same order as the pyramid is sometimes developed, and probably corresponds to that noticed upon the crystals of the foregoing type. Most of the crystals of these cavities, while very perfect and distinctly recognizable as pachnolite, are too small and their surfaces are too frequently covered by minute crystals of a later growth to be available for measurements with the goniometer. Two specimens, however, of the bluish massive material, when carefully examined, proved to contain pachnolite in a form allowing of more exact crystallographical, optical, and chemical investigation.

CRYSTALLOGRAPHICAL DETERMINATIONS.—The first of the specimens above mentioned, which we will designate specimen A, is about $8 \times 5 \times 2^{cm}$ in size, is somewhat more coarsely granular than the variety just described, and possesses in an eminent degree the regular structure there observed. While compact in the greater part of the specimen, there are portions in which the grains are more loosely aggregated together, and parts of individuals have perfectly developed crystal faces. In some minute cavities a few crystals with quite perfect terminations were found, and upon these some faces were sufficiently large and polished to admit of measurements with a Fuess reflection goniometer. These crystals are about 1^{mm} long and nearly the same in thickness. They show ∞P, $0 P$, with subordinate $-P$, and a negative pyramid determined, as $-3 P \bar{3}$. They are all twinned parallel to $\infty P \bar{\infty}$, and the low projecting angle upon $0 P$ is sometimes distinctly visible.

The angles given in the following table are all means of numerous closely agreeing measurements and demonstrate the crystallographical identity of the mineral under discussion with pachnolite:

Angle.	Crystal *a*.	Crystal *b*.	Other crystals.	Calculated.
	° ′	° ′	° ′	° ′ ″
$\infty P \wedge \infty P$	81 19	81 22	81 18	81 24
$\infty P \wedge 0P$		90 21	90 21	90 20
$-P \wedge 0P$		116 39	116 30	116 30
$-3P\bar{3} \wedge -3P\bar{3}$	138 45		138 45	138 52 14
$-3P\bar{3} \wedge \infty P$	149 03			149 07 19
$0P \wedge 0P$ (twin)		179 21		179 20

The face $-3P\bar{3}$ was observed on a number of distinct twin crystals, with projecting angle on 0P, and in several cases on both of the negative angles.

Upon one side of specimen A are a few thomsenolite crystals, distinguishable by their prism angle of nearly 90°. They lie irregularly, and seem to be later in formation than the pachnolite. Upon them are deposited minute prosopite crystals and indistinct alteration products. In the mass of this specimen no thomsenolite can be detected, while all individuals with partially free development are plainly pachnolite. Analysis XXVIII of the table (p. 54) was made upon material obtained from the clear loosely granular portions of specimen A, and although it was necessary to include many transparent grains of irregular shape, in order to obtain a desirable amount of substance, there is no doubt in our own minds that thomsenolite was wholly absent from the material analyzed.

The second specimen, B, from which especially good material was obtained, had a seam 2^{cm} thick of coarse granular structure running through it, and upon splitting it open along this seam two surfaces of water-clear loosely adhering crystalline grains of pachnolite were exposed with the regular arrangement described. Actual development of crystal faces other than the prism is rarer than in specimen A, but the size of the grains, reaching 5^{mm} in length by $1-3^{mm}$ in thickness, is such as to admit of the preparation of thin sections for optical examination, and also gave absolutely pure material for chemical analysis. None of the crystals upon which the faces were well formed were superior to those of specimen A, and only measurements of the prism angles were made. The face $-3P\bar{3}$ was not observed at all.

The optical properties of these pachnolite crystals are such as to leave no doubt concerning their crystallographical identity with the mineral described by Professor Groth as pachnolite. Several sections were prepared as nearly parallel to the clinopinacoid as possible. These exhibit in all cases a twin structure, and this is frequently polysynthetic. The twinning lines are straight and lie parallel to the vertical axis. Extinction takes place at 21° 30′ to 22°, or 68° to 68° 30′ from the twinning line, in opposed directions in alternate laminæ. According to Groth the bisectrix is in the plane of symmetry, and inclined 68° 5′ forward from the vertical axis. Sections parallel to the base also show the twinning structure, the line lying parallel to the orthodiagonal.

A large part of the purest crystals and fragments from this specimen were used for chemical analysis and repeated water determinations, the results of which are given below (XXIX, p. 54).

CHEMICAL INVESTIGATION.—Previous to the analysis by Brandl[28] of pachnolite carefully selected by Groth, pachnolite and thomsenolite were considered to possess the same chemical composition. The results of all earlier analyses, excluding such as referred to manifestly very impure material, while frequently deviating materially from the figures required by theory for the formula NaF, CaF_2, AlF_3, H_2O, still agree on the whole very well, as shown in the accompanying table, and fully justified the belief in the chemical identity of the two species.

	Thomsenolite.		Pachnolite.					
	Wöhler.[29]	König.[30]	Knop.[31]	König.[30]	Vom Rath[32]		Hagemann.[33]	Calculated for NaF, CaF_2, AlF_3, H_2O
Al	13.43	13.74	13.14	12.50	13.46	12.93	10.37	12.32
Ca	17.84	16.79	17.25	18.17	18.10	17.99	17.44	17.98
Na	10.75	10.10	*12.16	10.23	10.63	12.06	12.04	10.34
H_2O	8.20	9.00	9.60	8.19	....	....	8.63	8.10
F	49.78	50.87	50.79	51.54	....	....	51.15	51.26
	100.00	100.00	102.94	100.63	....	....	99.63	100.00

* Also, 10.80 and 10.81.

Wöhler's analysis was entirely confirmed some years subsequently by Jannasch,[34] in Göttingen, who analyzed pure thomsenolite selected by Klein.

In view of the above, the analysis of pachnolite by Brandl, showing results agreeing well with those required by the formula NaF, CaF_2, AlF_3, was calculated to cause no little surprise. Groth accepts without question the anhydrous nature of pachnolite, and endeavors to explain away the opposing evidence, shown in the foregoing table, by assuming that the supposed homogeneous material analyzed was contaminated largely with thomsenolite. As in no published analysis does the percentage of water fall below 7 per cent., this assumption necessitates a most improbable admixture of thomsenolite. In those cases where the percentage of water equals or exceeds that required for thomsenolite the presence of gearksutite is suggested by Groth as a possible explanation. Even on this supposition the percentage of foreign admixture could not fall below 50 per cent., in which extreme case the whole of the impurity must be gearksutite, an amount which it is difficult to conceive should have escaped the notice of such observers as König, vom Rath, and Knop, the latter of whom expressly says that his analysis was made upon material identified as pachnolite.[35] Notwithstanding the difficulty of explaining the agreement between the previous analyses of pachnolite and thomsenolite, on the assumption of the anhydrous nature of the former, the correctness of Brandl's analysis was not at first questioned by us.

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[28] Annalen der Chemie und Pharmacie, CCXIII, p. 6.

[29] Neues Jahrbuch für Mineralogie, etc., 1876, p. 851.

[30] Proceedings Acad. Sci. of Phila., 1876, p. 42.

[31] Annalen der Chemie und Pharmacie, CXXVII, p. 61.

[32] Sitzungsbericht d. niederrhein. Ges. für Natur.- und Heilkunde, 1860, XX, p. 141.

[33] Am. Jour. Sci., 1866, II, XLI, p. 119.

[34] Neues Jahrbuch für Mineralogie, etc., 1877, p. 808.

In the course of the present investigation the compact bluish material (see page 50), having the specific gravity 2.980 at 22° C., was first analyzed, the crystalline pachnolite not having yet been observed. The results of analysis as given under XXVI, below, agree in the main so well with the figures required for the formula NaF, CaF_2, AlF_3, H_2O, that no hesitation was felt in considering the mineral to be thomsenolite, probably slightly contaminated with fluorite. Later, the crystalline coating on the thin walls produced by the first mode of alteration of the cryolite, the crystals forming which had not yet been identified crystallographically as pachnolite, were subjected to analysis with the results given under XXVII. Here again the identity with thomsenolite seemed clear. It was not until the analysis of perfectly transparent fresh crystals and crystal fragments, all taken from specimen A, above described, gave the results shown under XXVIII, that the possibility of the first analyses having been also made upon pachnolite was suggested. That this was, however, so in the case of No. XXVII, subsequent careful examination fully revealed, though the crystals analyzed were not entirely free from foreign admixture. It seems certain, also, that the compact bluish portions (XXVI) consist almost entirely of pachnolite, although it cannot be positively asserted that some thomsenolite may not be intergrown with it. That no possible doubt might exist in the mind of any one as to the homogeneity of the material used for analysis XXVIII, a further analysis was made upon crystals from specimen B, above described, particular care being taken to identify each as pachnolite by the rhombic section. The results of this analysis appear under XXIX.

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[35] Neues Jahrbuch für Mineralogie, etc., 1876, p. 850.

	Hillebrand.							Brandl.[26]	Calculated for NaF, CaF₂, AlF₃, H O.
	XXVI.		XXVII		XXVIII.		XXIX.		
Al	11.94		12.93	12.92	12.14		12.27	13.51	12.16
Ca	19.32		15.27	15.17	18.06		18.04	18.83	18.02
Mg	0.13		1.53						
Na	10.43		10.28		10.23		10.25	11.73	10.36
K			0.13						
H_2O	7.87	7.95	8.64	8.79	8.10	8.11	8.05		8.11
F					51.33	51.28	*51.39	55.69	51.35
					99.88		100.00	99.76	100.00

*By difference.

. Further determinations of water, on material from specimen B, gave 7.95, 7.99, 8.14, and 8.15 per cent. Still other determinations, some on material every fragment of which showed the rhombic section, others on material taken at random from the crystalline mass, gave results between 7.90 and 8.20 per cent. The specific gravity at 17°C. of the perfectly pure material, as the mean of four determinations varying between 2.963 and 2.968, was 2.965. A single determination on another portion, equally pure, at 22°C. gave 2.962. The transparent crystals, as well as all the other portions analyzed decrepitated violently on heating in a test tube, the walls became lined with the white deposit so characteristic of thomsenolite and pachnolite, and much water was given off. Hence it appears that the pachnolite from Pike's Peak and thomsenolite are identical in composition, unless the fact of all analyses of thomsenolite showing slightly more water than required for the formula NaF, CaF_2, AlF_3, H_2O may indicate, as suggested by Groth, a partial replacement of fluorine by hydroxyl in that mineral. Should this prove to be the case, a plausible explanation of the difference in crystallization of the two minerals is offered without recourse to the theory of dimorphism.

A satisfactory explanation of Brandl's results, so opposed to those presented by all earlier analyses and the ones above given, is impossible, but it may be well to call attention to the fact that Brandl was obliged to make his determinations of fluorine and the metals upon quantities of 0.1106 gr. and 0.1430 gr. weight respectively, whereas material was not wanting for the present analyses, the determinations having been made upon weights of from 0.3 gr. to 0.75 gr. It nowhere appears that a direct test for water was made upon the material furnished by Groth. The latter, it is true, remarks (*l. c.* p. 461): "*Ausserdem bildet sich bei letzterem* (Thomsenolite) *in den kälteren Theilen des Rohres ein Wasserbeschlag, welcher beim Erhitzen reinen Pachnolithes natürlich ausbleibt.*" The absence of water does not, however, seem to be hereby proven, but simply to be assumed from the close approximation to 100 of Brandl's results, exclusive of water. Brandl himself says water is wanting, but does not mention whether this was ascertained by direct experiment. The small amount of material at his disposal renders it not improbable that no direct test was made.

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[26] Annalen der Chemie und Pharmacie, CCXIII, p. 6. The percentage of Al is calculated to correspond with the other analyses (Al=27).

Since the conclusion of the above investigations, through the kindness of Mr. Albert F. Damon, president of the Pennsylvania Salt Manufacturing Company, we have obtained specimens of Greenland cryolite and its alteration products. From one of these specimens was removed a large number of small, needle-like, pyramidally terminated, twinned crystals with a rhombic prismatic section, showing in fact precisely the common occurrence[37] and ordinary habit of pachnolite[38] as described by Groth. These crystals, slightly yellowish in color, but quite transparent, were individually examined under the microscope, all such as did not show beyond a doubt the above described habit being excluded. They were then tested in a small glass tube for water. Decrepitation ensued on heating and the walls of the tube became lined with a white powder, and also with a deposit of water, in such quantity as to preclude the possibility of its having been derived from but a small portion of the material experimented upon.

OTHER FORMS OF PACHNOLITE.—In some very cellular specimens, whose walls run irregularly and seemingly without reference to the cleavage of the original cryolite, are crystals of pachnolite of different habit from that so far described.

One or two of these cavities show crystals corresponding in size to those upon the thin walls, but exhibiting each and every one a re-entering angle on the free termination. In such little crystals the basal planes are prominent, and they are bounded on the inside by a pyramid and dome, doubtless $-P$ and $-P\breve{\infty}$. Outward there sometimes appears another pyramid ($+P$?), though the prismatic faces themselves usually form a sharp edge with $0P$. All these crystals are too small for measurement, but as the appearance described is such as would be normal for the termination by which the twin crystals are commonly attached, it seems admissible to consider the faces as $0P$, $-P$, $-P\breve{\infty}$ and probably $+P$. On many twins of this kind the outer or positive angles between ∞P and $0P$ are replaced by two faces greatly resembling those of $-3P\bar{3}$, and although entirely too minute for measurement it is probable that this form $-3P\bar{3}$ is here represented. The crystals of Greenland pachnolite are always attached by the end with the re-entering angle, according to Groth.

THOMSENOLITE.

OCCURRENCE AND DESCRIPTION.—While it is quite certain that thomsenolite is present in small quantity with the pachnolite, it has been impossible to obtain any quantity of it for examination. The microscopical study of the minute crystals lining the thin walls described, shows a few of nearly square section with sharp pyramidal form and destitute of a twin structure. These are usually deposited with corresponding ones of pachnolite in a wholly irregular manner upon the low crystals of pachnolite forming the main portion of the walls. The reflecting surfaces of the massive product show under the lens distinctly rhombic facets or striated planes; and thin sections, which reveal the characteristic twinning of pachnolite, afford no reason for suspecting the presence of thomsenolite here in any considerable quantity.

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[37] P. Groth, *l. c.*, p. 461.

[38] P. Groth, *l. c.*, p. 462.

The statement already made for a single case (p. 51) is probably true for all cases where thomsenolite has been noticed, viz., that it is later in formation than the greater part of the pachnolite, although the latter mineral is usually present in a second generation, as contemporary with the thomsenolite. No chemical identification has been possible, but the nearly square section, perfect basal cleavage, and absence of twinning are under the circumstances quite sufficient proofs.

In many cavities, arising from both modes of decomposition of the cryolite, a second series of minerals has been deposited, chiefly as a whitish, easily crumbling aggregate of minute crystalline grains, which are recognizable under the microscope as thomsenolite, pachnolite, and a mineral of the isometric system. The difference in habit of the former two species is here quite plain, for some of the little crystals of thomsenolite are doubly terminated and show distinct monoclinic symmetry in spite of the square section, through the more prominent development of the negative pyramid, while pachnolite seems perfectly rhombic in form, through its twinning.

RALSTONITE.

PROBABLE IDENTIFICATION.—This rare species, originally described by Brush,[39] from microscopic crystals, has been more definitely determined by Groth and Brandl. Its chemical composition is, according to Brandl, expressed by the formula $3NaF, 4AlF_3, H_2O$, a small part of the sodium being replaced by calcium. The crystals are of the isometric system, and represent the cube modified by the octahedron.

Groth's description of the occurrence of the mineral agrees very closely with that of the isometric mineral mentioned above as appearing with a recent generation of thomsenolite and pachnolite. The crystals here found are transparent cubes whose corners are replaced by small octahedron faces and seldom reach a diameter of 1^{mm}, while sinking to microscopic size. Some crystals of pachnolite seem by a low magnifying power to be coated by a crystalline dust whose particles are found, by applying a high power, to be most perfect little crystals of the form just mentioned. These sometimes unite to form a crust. No material for a chemical test could be secured, but the analogy in form and occurrence is so complete that scarcely a doubt can exist of the identity of these beautiful little crystals with the species ralstonite, although another mineral of the same crystal system is now to be described.

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[39] G. J. Brush, Am. Jour. Sci., III, II, 30, 1871.

ELPASOLITE, A NEW MINERAL.

Just at the close of our investigations a mineral was found, occurring sparingly in a few specimens, which seems to be very different from any known species. It was found in small cavities in the massive pachnolite as a compact irregular mass, colorless but not perfectly clear, and exhibiting but seldom traces of crystalline form. In one specimen, however, the mass of the mineral was covered by small rounded crystal-like projections, which seemed like crystals of the isometric system. An examination with a loupe showed the absence of recognizable faces, but such particles when broken off and tested under the microscope proved to be fully isotropic. A few faces found on one crystal seemed to belong to cube and octahedron, and particles detached from the same are isotropic in action in polarized light. Supposing that this substance must be ralstonite in exceptional development, enough material for the following partial chemical analysis was selected, being carefully freed from attached particles of pachnolite and other anisotropic minerals by microscopical examination. The Al, Ca, and Mg were accurately determined, the K and Na, owing to an unfortunate mishap, only approximately. No water could be detected by direct test upon a small portion. Fluorine was present in quantity, and the percentage given below is calculated on the assumption that the metals are fully combined with it:

	XXX.
Al	11.32
Ca	0.72
Mg	0.22
K	28.94
Na	9.90
F	46.98
(W. F. Hillebrand.)	98.08

From this analysis may be derived a formula analogous to that of cryolite, in which about two-thirds of the sodium is replaced by potassium.

The imperfections of the above analysis do not allow of definite conclusions as to the composition of the mineral, but it is nevertheless widely different from any known mineral species, while the purity of the substance is shown by its isotropic action in polarized light. Since the original description of the mineral[40] the locality has been revisited in the hope of obtaining more material, but the spot was at the time inaccessible, so that we can offer no further data concerning this interesting new species. We wish to propose the name *elpasolite* for it, from the county El Paso, which embraces the greater part of the Pike's Peak region. Further investigations as to the properties of the mineral will be made as soon as material can be procured.

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[40] Am. Jour. Sci., III, XXVI, 283, 1883.

GEARKSUTITE.

General Description.—This mineral, first observed by Hageman[41] on compact thomsenolite, and described as earthy and kaolin-like in aspect, dull white, opaque, and of hardness 2, seems to be so rare in connection with the Greenland fluorides that no one has had material for further examination. Groth[42] found it in very small quantity among the minerals at his disposal, but could not obtain enough for analysis. He found, however, that it consisted of very minute microscopic needles, with oblique extinction, and considers it as undoubtedly a definite species.

Among the minerals from St. Peter's Dome gearksutite is quite abundant. It is not formed from other minerals by molecular replacement, but is deposited from solution in cavities upon fresh crystals of pachnolite, etc. The smaller cavities are sometimes filled by it, and on the contact with the quartz it is specially developed.

In appearance it corresponds closely to the description of the Greenland mineral as given by Dana, the resemblance to the purest, finest kaolin being especially remarkable. Examined microscopically, gearksutite is seen to consist, as stated by Groth, of exceedingly minute colorless needles, the average length of which is less than 0.02^{mm} and the thickness less than 0.002^{mm}, and apparently possessing oblique extinction.

Chemical Investigation.—Gearksutite was found by Hagemann (*l. c.*) to possess the following composition:

Al	15.52
Ca	19.25
Na	2.46
H_2O	20.22
F	41.18
	98.63

An examination of the above results shows that the atomic ratio of $Al : Ca + Na_2 : F$ is 1:1:4, instead of 1:1:5, which would represent complete saturation and require about 12 per cent. more fluorine than was found. On the assumption that the missing fluorine is replaced in the mineral by oxygen or hydroxyl, there should appear a much greater loss than the analysis indicates. An error is therefore evident, probably in connection with the determination of the fluorine or of the water, or both, in consequence of which the construction of a satisfactory formula has heretofore been impossible.

The material for the following analyses was first partially crushed, then freed from admixed heavier particles of foreign matter by triturating in a beaker with water, the impurities falling to the bottom of the vessel, while the light gearksutite remained suspended in the liquid and was removed by decantation. By repeating this operation a great many times a product was finally obtained entirely free from all foreign admixture. It was allowed to settle completely, the supernatant liquid poured off and the residue dried first on the water bath, then at 100° C. Thorough pulverization of this residue is a difficult matter, as it flattens out under the pestle, forming flakes which strongly resist the pulverizing action. This is of little moment, however, since the flakes are so spongy as to offer no hindrance to attack by sulphuric acid. Two analyses were made from the same sample, with the results tabulated below. In *b* sodium and potassium were not determined:

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[41] Dana, System of Mineralogy, 5th ed., p. 130.

[42] Groth, *l. c.*, pp. 460, 481.

	XXXI.		
	a.	*b.*	Mean.
Al	15.22	15.19	15.20
Ca	22.29	22.32	22.30
Na	0.10	......	0.10
K	0.04	......	0.04
H_2O	15.54	15.39	15.46
F	42.14	42.01	42.07
	95.33	......	95.17
Loss as O	4.67	......	4.83
	100.00	......	100.00
(W. F. Hillebrand.)			

Taking the figures in the third column and combining the fluorine with the calcium, sodium, potassium, and, as far as possible, with the aluminium, there remains of the latter 5.35 per cent., requiring 4.76 per cent. of oxygen, an amount agreeing very well with that obtained above by difference and making the sum total almost exactly 100:

22.30 Ca	requires 21.18 F.
0.10 Na	requires 0.08 F.
0.04 K	requires 0.02 F.
9.85 Al	requires 20.79 F.
10.11 Al_2O_3	———
15.46 H_2O	42.07
42.07 F	
———	
99.93	

The agreement of the above analysis with that of Hagemann, after substituting in the latter for the sodium its equivalent in calcium, is very close, with the single exception of the water. As his analysis was manifestly erroneous in some particular, the assumption of the identity of gearksutite with the mineral here discussed is fully justified, supported as it is by the similarity in occurrence, appearance, and physical characteristics. His error would then consist in having obtained from 4 to 5 per cent. too much water, a result not difficult of explanation in the case of a hydrated fluoride, if no precaution was taken to prevent the escape of fluorine.

Substituting in the mean of analyses *a* and *b* for sodium and potassium their equivalent of calcium, and dividing the percentages by the atomic weights, the atomic ratio is found to be as given below:

Al ...... $15.20 \div 27 = 0.563$
Ca ...... $22.41 \div 40 = 0.560$
H_2O ...... $15.46 \div 18 = 0.859$
O ...... $4.76 \div 16 = 0.297$
F ...... $42.07 \div 19 = 2.214$

The ratio of Al : Ca : F is here nearly as 1 : 1 : 4, the same as found by Hagemann. Subtracting from the atomic value for water an amount 0.297 equal to that for oxygen, in order to form with the latter hydroxyl, the result is as given in the first column below, while in the second appears the ratio referred to calcium as unity.

Al	0.563	1.005	
Ca	0.560	1.000	
H_2O	0.562	1.004	
HO	0.594	1.061	5.015
F	2.214	3.954	

It will be seen that by combining hydroxyl and fluorine the ratio $Al:Ca:H_2O:(F,OH)$ is 1:1:1:5, and the formula for the mineral becomes CaF_2, $Al(F, OH)_3$, H_2O, in which the fluorine and hydroxyl combined with the aluminium, stand nearly as 2:1. Were the latter proportion exactly fulfilled, the formula might be written $3CaF_2$, $2AlF_3$, $Al(OH)_3$, $3H_2O$, requiring the percentages: Al 15.17, Ca 22.47, F 42.69, O 4.50, H_2O 15.17=100.00.

Of the 15.46 per cent. of water found by analysis, 5.35 per cent. has been considered in the foregoing as basic. While this amount may, on theoretical grounds alone, enter into the inner constitution of the mineral as basic water, the remainder cannot, but must be water of crystallization. That a portion of the water is basic is rendered more than probable by the fact that at 300° C. some is still retained. In this connection the following experiments were made: 0.5677 gram of the mineral, not, however, from the same sample as that used for analysis, dried first at 100° C. and contained in a platinum crucible, was exposed in an air bath during 145 hours to temperatures ranging from 100° C. to 300° C., the weight being taken at intervals averaging 10 hours each. The results in brief showed that at 145° C. the loss was but 0.35 per cent., at 230° C. only 0.92 per cent., at 250° C. 7.02 per cent., after prolonged heating at 265°–270° C. 9.49 per cent., and at 295° C. 13.92 per cent. As no further loss occurred after six hours heating at 295°–300° C., a portion of the residue which still retained its original appearance was subjected to a quantitative test for water, of which 1.76 per cent. was found.

This added to the 13.92 per cent. driven off below 300° C. made the total 15.68 per cent. Since this is slightly higher than the mean of the previous results, it seemed possible that some fluorine might have escaped. The remainder of the residue was therefore tested quantitatively for fluorine, of which was found 40.60 per cent., thus apparently proving the correctness of the surmise. A similar experiment with the same general results was made upon a smaller portion of another sample. A comparison of the full results of both experiments showed that by sufficiently prolonged heating at approximately 270° C. all the water of crystallization could be driven off; also that by still further heating at little if any higher temperature the basic water began to escape, but was not entirely expelled even after many hours exposure to a temperature of 295°–300° C.

While these experiments cannot be considered as affording any conclusive proof that the water in this mineral is to be reckoned as water of crystallization and basic water in the above given proportions, since at the point when the last of the former is driven off by heat some of the latter appears also to escape, still the belief that this should be done is a natural one and is supported by the fact (which may possibly, however, be merely the result of accident) that by so doing the ratio of calcium to water of crystallization is exactly 1:1, while if all the water is assumed to be water of crystallization the ratio is 1:1.534 or 2:3.068.

Evigtokite.—In the Journal of the Chemical Society for 1883, p. 140, Walter Flight describes a mineral obtained from the cryolite bed of Greenland. "It is made up of a congeries of minute white transparent crystals, mostly broken up and lying entangled among each other in every sort of direction, which gives the mass an appearance of opacity much resembling that of kaolin or chalk."

Chemical analysis showed it to consist of—

		Equivalents.
Al.......16.28 with F 33.64 =	49.87	0.59
Ca.......22.39 with F 21.27 =	43.66	1.12
Na....... 0.43 with F 0.33 =	0.76	
	94.29	
Water..................	5.71	0.63
	100.00	

The fluorine seems to have been calculated for the metals, and the water was found by difference.

From the above data the author obtains the formula $2CaF_2$, Al_2F_6, $2H_2O$,[43] and, considering the mineral new, names it evigtokite.

Mr. Flight seems to have overlooked the description of gearksutite in Dana's System of Mineralogy and Professor Groth's remarks upon the same (l. c., pp. 481 and 493), else the very fair agreement of his analytical data for the metals with those of Hagemann, and the similarity of occurrence, appearance, and physical characteristics of the two minerals, must have led to at least a suspicion of their identity. There can hardly exist a doubt that Flight has analyzed gearksutite and that the name evigtokite is therefore to be dropped.

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[43] Probably a printer's error. It should read $2CaF_2$, Al_2F_6, H_2O.

PROSOPITE.

OCCURRENCE.—This rare species, hitherto unobserved in association with the cryolite minerals and known only in connection with the tin-bearing veins of Altenberg in Saxony, has been identified at St. Peter's Dome.

Both of the coarsely crystalline specimens of pachnolite, above described as A and B, have prosopite upon them. Specimen B is in parts in process of alteration to a dull white substance with little cavities in which are minute crystals of prosopite. These are colorless, transparent, tabular in shape, agreeing exactly in form and optical behavior with those determined as prosopite by chemical analysis. In two other specimens of pachnolite prosopite tablets may be seen upon certain granular surfaces when decomposition of the pachnolite has already begun. The crystals are usually attached by the prismatic edges, although free and perfect terminations are to be found. Gearksutite was noticed upon them in one specimen and the position of prosopite in the series of hydrous fluorides is doubtless between thomsenolite and gearksutite. No material for chemical tests could be procured from the specimens described.

The penetration of the fluoride mass by astrophyllite blades springing from the side of the vein has been mentioned (p. 42). Here the cryolite has been altered to cellular pachnolite, according to the first mode described, and this has for the greater part given way to other products and been dissolved and carried away, leaving the astrophyllite blades more or less free or imbedded in gearksutite and other soft, crumbling material. The free blades usually have a coating composed of a little purplish fluorite, and over this a nearly colorless or slightly yellowish substance. At and toward the base of the astrophyllite blades the latter is present in roundish aggregates made up, as shown by the lens, of clear tablets, in more or less radiate arrangement The crystal form is here quite obscure, but the general appearance was so suggestive of prosopite that by sacrificing the best specimen enough material was obtained for determination of the bases and of fluorine, with the result given below, XXXVI, p. 64.

Adjoining the quartz in the Eureka mine is usually an irregular zone of purplish or greenish fluorite, and next to this a rather coarsely granular mass of a colorless mineral, with two distinct cleavage planes, which passes gradually into the compact white substance beyond. This zonal arrangement is not without exceptions, for both granular and compact masses come directly in contact with the quartz in some specimens, and fluorite is more or less abundantly sprinkled through the other substances; in fact, the relation of the minerals to each other is such as to indicate that they are but different phases of alteration from a common source. The granular mineral occurs in sufficient purity to afford material for chemical analysis, and its individuals are large enough to admit of the preparation of thin sections, with definite relations to the cleavage planes. The analysis first proved the identity of this mineral with prosopite, the optical properties shown by the thin section confirmed this determination, and a few minute crystals were found in one specimen, which agree with the published data on the Saxon mineral. As the identification of this rare species, particularly in its present association, is a matter of considerable interest, we will describe it somewhat in detail.

CRYSTALLINE FORM AND PHYSICAL PROPERTIES.—The minute crystals observed are all of the habit shown in Fig. 11 of the plate. This is from a camera lucida drawing of a crystal measuring 0.5^{mm} normal to the edge of the prism, and can therefore make no pretensions to crystallographic accuracy. The crystals are colorless and transparent, have uniformly a tabular form through the development of $\infty P \breve{\infty}$, and show mainly the prism and two pyramids, which may be considered as P and $-2 P \breve{2}$, for extinction takes place nearly or quite parallel to the edge of $-2 P \breve{2}$, which is, according to Des Cloizeaux[44] and Groth,[45] the position of the bisectrix.

Thin sections prepared as nearly as possible perpendicular to the edge of the two cleavage faces in the irregular granular individuals, show that the angle of the cleavage planes is very nearly 135°, and that extinction takes place parallel to the direction bisecting that angle. This behavior agrees perfectly with the statements concerning prosopite, according to which the chief cleavage is parallel to $-2 P \breve{2}$, the angle of which is about 134°. The present material does not allow of a definite settlement of the question of the crystalline form of prosopite, but nothing observed is in conflict with the reference to the monoclinic system.

CHEMICAL INVESTIGATION.—The formula deduced by Brandl[46] for prosopite, from the results of his analysis as here given—

		Atomic values.
F	35.01	1.842
Al	23.37	0.853
Ca	16.19	0.405
Mg	0.11	0.004
Na	0.33	0.014
H_2O	12.41	0.689
Loss as oxygen	12.58	0.786
	100.00	

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[44] Bull. Soc. Min. de Fr., V, 317.

[45] *l. c.*, p. 290.

[46] Annalen der Chemie und Pharmacie, CCXIII, p. 13.

is $CaF_2, 2Al(F,OH)_3$. The whole of the water is assumed to be basic, entering with oxygen into the constitution of the mineral as hydroxyl, the latter replacing an equivalent amount of fluorine. In support of this assumption Brandl mentions that no loss is perceptible below 260° C.

In an earlier partial analysis Scheerer (Pogg. Ann., CI, p. 361) found Al 22.77, Ca 16.41, H_2O 15.50.

Of the analyses tabulated below, those under XXXII, XXXIII, XXXIV, and XXXV were made upon material from vein B. That analyzed under XXXII, *a* and *b*, was composed of comparatively large irregular crystalline pieces showing no visible impurity whatever, having a specific gravity at 23° C. of 2.880 and a hardness of about 4.5. As the ratio Al : Ca differed materially from that of 2:1, required by Brandl's formula, it appeared that some foreign matter must be present, consequently no further determinations were made, as it was hoped better material might be obtained.

Analysis XXXIII was made upon material separated from quartz, zircon, fluorite, and other accompanying minerals, by a solution of iodide of mercury in iodide of potassium. The result was a slight improvement, and the analysis was completed. The material for XXXIV was picked out carefully by hand with the aid of a lens, but as the result was still unsatisfactory, a further portion (XXXV), aggregating, however, only 0.1022 gram, was selected with the greatest possible care, every particle being distinctly crystalline, and showing under the microscope no trace of impurity. Here a slight improvement becomes evident in the ratio, but as the amount taken for analysis was so extremely small, it cannot be asserted that the better results may not be due to unavoidable errors of analysis. The material for analysis XXXVI was derived from the crystals occurring on astrophyllite. This material was, however, evidently not quite pure, being opaque and very slightly colored in part by oxide of iron. The analysis was made merely to prove its identity with the prosopite of the other occurrence.

	XXXII.		XXXIII.	XXXIV.	XXXV.	XXXVI.
	a.	*b*.				
Al	21.94	21.68	21.88	22.13	22.49	21.64
Ca	17.67	17.87	16.92	17.14	16.80	16.84
Mg	....	....	0.20	....	0.15	0.35
Na	....	....	0.48	....	0.48	0.79
K	....	....	....	....	....	0.11
H_2O	....	....	*13.54	....	....	....
F	....	....	33.14	33.22	....	32.30
	....	....	86.16	....	....	....
Loss as oxygen	....	....	13.84	....	....	....
(W. F. Hillebrand.)	....	....	100.00	....	....	....

* And 13.37.

The mean of analyses XXXII–XXXV is as follows:

Al	22.02
Ca	17.28
Mg	0.17
Na	0.48
H_2O	13.46
F	33.18
	86.59
Loss as oxygen	13.41
	100.00

After subtracting from the fluorine an equivalent for the calcium, magnesium, and sodium, and combining the remainder with aluminium, there remains of the latter 14.39 per cent., requiring 12.79 per cent. of oxygen, instead of 13.41 per cent. found by difference. The atomic values appear as follows, after substituting for magnesium and sodium an equivalent of calcium:

$$\begin{array}{l}
\text{Al}\ldots\ldots 22.02\div27=0.815\\
\text{Ca}\ldots\ldots 17.98\div40=0.449\\
\left.\begin{array}{l}\text{F}\ldots\ldots 33.18\div19=1.746\\ \left.\begin{array}{l}\text{H}_2\text{O}\ldots 13.46\div18=0.748\\ \text{O}\ldots\ldots 12.79\div16=0.799\end{array}\right\}1.547\end{array}\right\}3.293
\end{array}$$

The result is unsatisfactory, the ratio of Ca: Al being 1 : 1.81 instead of 1 : 2. In none of the material analyzed was the slightest trace of kaolinization to be observed, nor any other foreign matter. It therefore becomes impossible to explain with any degree of certainty the above abnormal results.

The general agreement of all the analyses, the aluminium being found too low and the calcium too high in each case, shows pretty conclusively that an explanation cannot be sought for in analytical errors.

As fluorite occurs here always in most intimate association with prosopite, and the possibility suggested itself that some of this might be so intergrown with the latter as to escape the closest scrutiny, it became desirable to ascertain what change would be effected in the ratio above given by subtracting enough calcium to make the ratio Ca : Al as 1 : 2, and an equivalent amount of fluorine. The atomic values then become:

$$\begin{array}{lll}
\text{Al}\ldots\ldots 0.815 & & 2.00\\
\text{Ca}\ldots\ldots 0.408 & & 1.00\\
\left.\begin{array}{l}\text{F}\ldots\ldots 1.664\\ \text{HO}\ldots\ldots 1.547\end{array}\right\}3.211 & & 7.87
\end{array}$$

which agree nearly as well for the formula Ca, Al_2 $(F, OH)_8$ as those obtained by Brandl.

If, instead of the mean of all the analyses, the figures of XXXIII alone are taken for calculations similar to the above, the result is the same, even a little more closely approximating to the ratio 2 : 1 : 8.

The prosopite is much less readily attacked by sulphuric acid than the other fluorides described, and unless the pulverization is very thorough a small portion is generally left undecomposed even by boiling acid. To this fact may possibly be due the deficit of nearly 2 per cent. in fluorine, as compared with Brandl's results. On the assumption that 35 represents more nearly than 33.18 the true percentage of fluorine in the mineral analyzed, the ratio of water to required oxygen after combining all fluorine is 1 : 1.005, instead of 1.068. Allowing, then, for possible admixture of fluorite as above, the ratio Al : Ca : F+OH is 2.00 : 1.00 : 7.99, almost exactly 2 : 1 : 8.

The observation made by Brandl that below 260° C. no loss in weight occurs, was found to apply here, provided the exposure to this degree of temperature is short. If continued for many hours a slight but sensible loss is observed.

ZIRCON.

General Occurrence.—Zircon is one of the most widely distributed minerals of the region, occurring as an associate of nearly all other species in veins and druses and also impregnating the granite itself. König[47] has described it as an associate of astrophyllite and as intergrown with microcline. In its usual form it is brown or nearly black in color, and has only the ground pyramid and corresponding prism, the latter quite subordinate. König identified the basal plane 0P, and it seems to appear in very minute form upon crystals of all modes of occurrence though on comparatively few from each place. Sometimes the zircon crystals are more than an inch in diameter, sacrificing perfection to size, as there is commonly more or less distortion of angles and unevenness of surfaces in such individuals.

Zircon from the Eureka tunnel.—Reference has already been made in describing the occurrence of cryolite to the mutual relations of the different parts of the irregular vein into which the Eureka tunnel has been driven. The part containing zircon is but small, comparatively, and is sharply defined. It evidently represents a contemporaneous formation of quartz, zircon, and microcline. Zircon crystals varying in size from less than 1^{mm} to 1^{cm} are very plentifully and uniformly scattered throughout, while small patches of reddish microcline were also included in the more abundant quartz and themselves inclosed numer small zircons. The occurrence is noteworthy from the perfection in form and the transparency of the zircon.

The zircon crystals imbedded in quartz are sometimes perfect, but in most cases the formal development has been hindered by the surrounding mineral, producing striated or distorted faces. These crystals, too, are much shattered by the jars of the blasting and the blows necessary in breaking up the larger pieces. Those smaller crystals deposited in the microcline were able to develop freely and they are now found imbedded in pure white kaolinite or a compact yellowish mica—the alteration products of the original microcline, some of which is yet visible. The nature of the surrounding material has protected these crystals from jars and also makes it possible to isolate single ones, absolutely unharmed, for examination. The color varies from a rich reddish brown to a light wine or honey yellow shade. A few minute crystals are of a deep emerald green and spots of similar color were noticed in some pinkish crystals. While a few are really gems in clearness and color, they are usually of the smallest size, and are those found in the kaolinite or mica.

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[47] G. A. König, Zeitschrift für Krystallographie, I, 423, 1877.

The common habit of all crystals is pyramidal, the prisms being always subordinate when they appear. The forms determined with certainty are P, 3P, 0P, 3P3, ∞P and $\infty P\infty$. The rare face 0P is much less frequently developed than any of the others, but it was observed distinctly on at least twenty-five crystals. Repeated measurements on different crystals of the angle $0P \wedge P$ give results varying less than 3′ from the calculated value (137°50′). Between 0P and P is a low pyramid appearing quite constantly with 0P, which forms an angle of 164° 46′ with P. This corresponds very nearly to $\frac{14}{25}P$. The angle between this form and P is replaced by a curved surface giving an almost continuous reflection, but the angle with 0 P is distinct. 0 P is often visible on but one termination, but it is by no means rare to find it upon both.

Chemical analysis shows this zircon to be exceedingly pure and the specific gravity of transparent crystals is 4.709 at 21° C.

KAOLINITE.

The chief alteration product of microcline in the Eureka vein proves to be a very pure kaolinite. Some of the large individuals are changed into a compact white foliate kaolinite in the mass of which the cleavage planes of the microcline are still indicated. In other cases a more coarsely foliate aggregate is formed, the single leaves of which are beautiful transparent crystals.

The smaller patches of microcline deposited in the zircon-bearing quartz are also changed into kaolinite or a yellow micaceous mineral whose analysis accompanies that of the kaolinite below. Sometimes small cavities in the quartz contain single projecting crystals. These are exceedingly thin, colorless, transparent, rhombic leaves, the acute angle being usually evenly truncated, producing sometimes an almost perfect hexagon. The result of many measurements under the microscope seems to indicate that the obtuse angle of the rhomb is slightly less than

120°, the best results varying from 118° 30′ to 119° 30′. The thinnest leaves show distinct action on polarized light and extinguish parallel to the diagonals of the rhomb. The thicker crystals are made up of many tablets which are usually not perfectly coincident in position and sometimes form more or less perfect rosettes. The kaolinite possesses the composition XXXVII, and the mica XXXVIII, as given below. The kaolinite contained a small amount of fluorite in almost microscopic crystals, the quantity being calculated from the Ca found.

	XXXVII.				XXXVIII.
	a.	b.	Mean.		
SiO_2	45.91	46.22	46.06	SiO_2	52.59
Al_2O_3	39.65	39.62	39.63	Al_2O_3	29.72
H_2O	13.77	......	13.77	Fe_2O_3	1.40
CaF_2	0.68	....	0.68	CaO	0.26
				MgO	2.12
	100.01		100.14	K_2O	8.33
				Na_2O	0.50
				H_2O	4.39
					*99.31
(W. F. Hillebrand.)				(W. F. Hillebrand)	

* The presence or absence of fluorine was not ascertained.

Oxygen ratio of XXXVII:

$$Al_2O_3 : SiO_2 : H_2O.$$
$$3.05 : 4.01 : 2.02.$$

The kaolinite has nearly the theoretical composition, while the mica is probably a variety of muscovite.

PHENACITE.

From Crystal Park.—This mineral was first identified from two crystals found in association with topaz in Crystal Park, near Manitou. Subsequent search revealed a number of others at the same place, but as they are inferior to those originally described[48] no new data can be given of this occurrence. The crystals found are but fragments, representing in each case somewhat less than half of the complete crystal. Fig. 12 of the plate represents one crystal in about the natural size; another measures nearly 7cm in longest diameter, and has the same faces developed in similar manner. In no crystal do any faces of the vertical zone appear, thus producing a flat lenticular habitus. The forms appearing have been identified as $R, -\frac{1}{2}R, -R$ and $\frac{2}{3}P2$, and although the faces are too rough to admit of exact measurements with the reflection-goniometer, the size of the faces and their simple development render sufficiently accurate results with the hand instrument possible. The angles obtained as means of several measurements are:

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[48] Am. Jour. Sci., III, XXIV, p. 282, October, 1882.

	Crystal *a* (Fig.)	Crystal *b*.	Authorities.
	° ′	° ′	° ′ ″
R ∧ R (terminal)	....	116 20	116 36 (D)
R ∧ R (lateral)	....	63 00	63 24 (S)
R ∧ $-\frac{1}{2}$R (over $\frac{2}{3}$P2) ...	148 30	148 50	148 18 (D)
R ∧ $\frac{2}{3}$P2	159 45	159 58	159 56 (D&S)
R ∧ −R	74 30	74 40	74 42 45 (S)
$-\frac{1}{2}$R ∧ $-\frac{1}{2}$R	143–144 00	....	144 1 26
$-\frac{1}{2}$R ∧ −R	....	163 43	103 32 2
$\frac{2}{3}$P2 ∧ $-\frac{1}{2}$R	168 11	168 50	108 22 (S)
$\frac{2}{3}$P2 ∧ $\frac{2}{3}$P2	156 40	156 00	156 44 (D&S)

The figures of the third column are the calculated angles given for phenacite by Dana[49] or Seligmann,[50] or else our own calculations based on the theoretical values given by them. The agreement between the angles measured on these crystals and the theoretical ones is sufficiently close to justify the signs given to the faces of the figures. In the development of the different forms R and $-\frac{1}{2}$R are always prominent, while the faces of $\frac{2}{3}$ P2 are variable. One face of $\frac{2}{3}$ P2 on crystal *b* is 2.5^{cm} broad, although usually each face of $-\frac{1}{2}R$ is broader than both adjoining faces of $\frac{2}{3}$ P2; −R is subordinate and the faces are quite rough; $\frac{2}{3}$ P 2 appears with its full complement of faces. The roughness of the faces is in part caused by striæ, which on − $\frac{1}{2}$ R and $\frac{2}{3}$ P2 run parallel to the terminal edge of R replaced by those faces. On R the markings are less distinct. These striæ and partially regular depressions seem like natural etching figures, and bring out the rhombohedral symmetry of the mineral very plainly.

The crystallographical determination of these minerals as phenacite is confirmed by all the physical characteristics as far as observed and by the chemical composition. There is an imperfect cleavage parallel to ∞ P2. Both crystals are clear and colorless, resembling quartz, and the hardness is nearly or quite 8. The specific gravity of the crystal figured, though containing some impurities, is 2.967 at 23° C.

PHENACITE FROM NEAR FLORISSANT.—Another occurrence of phenacite was discovered during the summer of 1884, near Florissant, in association with the topaz crystals described later on. The crystals here are small, colorless, of lenticular form, and are deposited upon or slightly embedded in amazon stone crystals, in the same manner as the topaz, which is often present side by side with the phenacite. None seen exceed 5^{mm} in diameter, and crystals of this size in one case form an almost continuous crust upon the surface of a feldspar crystal. More commonly they are attached by an edge, although occasionally in all other positions.

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[49] Dana, System of Mineralogy, 5th ed., p. 263.

[50] G. Seligmann, in Neues Jahrbuch für Mineralogie, etc., 1880, I, 129.

These small crystals, while preserving the lenticular form of those from the first locality, exhibit a development of several new faces. These can be determined with considerable certainty by a reference to the article by Seligmann, reviewing the crystallography of the species.[51] All the present forms are mentioned by him as occurring with very nearly the same relative development upon the phenacite from the Ilmen Mountains, in the Urals. The zonal relations are almost sufficient to determine the new faces, although measurements were made to insure accuracy.

The new forms observed are: $-2R$, seen in a few crystals in good development; $-\frac{1}{2}R3$, which appears prominently with six nearly equal faces; $\dot{R}3$, of which only three faces were found on any crystal, and which is often not developed at all; ∞R and $\infty P2$, appearing as very narrow faces, which do not produce a prismatic habit in any case and are often wanting. A narrow face sometimes seen between R and $-\frac{1}{2}R3$ is probably $\frac{4}{3}P2$.[52]

TOPAZ.

Within the past two years topaz has been found in several places within the Pike's Peak region, and we can supplement our original notice[53] of the mineral quite materially.

Topaz has been found in Crystal Park, south of Manitou, in a cavity containing feldspars, smoky quartz, zircon, and phenacite; at the main amazon stone locality near Florissant, about 12 miles northwest from Pike's Peak; and, more plentifully and in better form than elsewhere, on Devil's Head Mountain (Platte Mountain), north of Pike's Peak about 30 miles.

Crystal Park.—Of the few crystals found in this locality the most perfect one measures 2.5^{cm}. parallel to the vertical axis, 3.3^{cm}. parallel to the brachy axis, and 2.8^{cm}. parallel to the macro axis. It is colorless and some parts of the crystal are very clear. The prisms ∞P and $\infty \breve{P}2$ are well developed. The terminations are drusy, although many of the prominences are large enough to admit of the determination of some of the faces which bound them. The pyramid $2P$ has been recognized with certainty, while a form between $\frac{2}{3}P$ and P, which is probably $\frac{4}{5}P$, and another pyramid near $2\breve{P}4$ are also present. Measurements of sufficient accuracy for the calculation of these latter forms could not be obtained. The lateral edges of these pyramidal prominences lie in a plane corresponding to the brachydome $2\breve{P}\infty$, and although that form does not actually appear, the crystal has a domatic habit. A rough face of $4\breve{P}\infty$ is present quite distinctly. While one termination is more perfect than the other, both are alike. Not more than a dozen crystals have been found in this locality.

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[51] G. Seligmann. "Krystallographische Notizen, I," Neues Jahrbuch für Mineralogie, etc., 1880, I, 129.

[52] An announcement of this locality was made by W. E. Hidden, Am. Jour. Sci., March, 1885, received after this article was written.

[53] Am. Jour. Sci., III, XXIV, p. 282, 1882.

FLORISSANT.—The first specimen identified from Florissant is mainly noteworthy on account of the enormous size of the original crystal from which it came. This specimen is but a corner of a large crystal, the forms appearing being two faces of $\infty\breve{P}2$, one of ∞P, and one each of $2\breve{P}\infty$ and $4\breve{P}\infty$. The fragment is about 9^{cm} (3½ in.) in its longest diameter, and if the other faces were developed to correspond to those here seen, the complete crystal must have been nearly or quite one foot in diameter parallel to the brachy diagonal. It is clear in parts and has a decided greenish tinge. It was supposed to be fluor spar by the original collectors, and the other pieces of the crystal are undoubtedly lost.

The specific gravity of this fragment is 3.578 at 22° C. and it has the following composition:

	XXXIX.
SiO_2	33.15
Al_2O_3	57.01
F	16.04
	106.20
O for F	6.75
	99.45
(W. F. Hillebrand.)	

Atomic ratio:

$$\begin{array}{c} Si \;:\; Al_2. \\ 1.025 : 1.000. \end{array}$$

Within a few months a further discovery of topaz has been made near Florissant. In this case the crystals were found deposited upon or partially imbedded in amazon stone, albite, or limonite (pseudomorph after siderite). The crystals seen by us are deposited upon different faces of the microcline and so seldom with any parallelism in position that any such coincidence must be considered accidental. In size the crystals vary from a length of nearly two inches to those which are almost microscopic. They are deposited singly or in groups and are attached in all positions, so that many of them are quite well terminated at both ends. The forms observed are as follows: ∞P and $\infty\breve{P}2$, both polished and striated; $4\breve{P}\infty$, $2\breve{P}\infty$, and $\frac{4}{3}\breve{P}\infty$; $0P$; $2\bar{P}\infty$; P and $\frac{2}{3}P$; $\infty\breve{P}\infty$.

Quite characteristic is the prominent development of the brachydomes $4\breve{P}\infty$ and $2\breve{P}\infty$, the former in particular, the faces of opposite terminations often meeting. $4\breve{P}\infty$ is almost uniformly dull, like ground glass, while $2\breve{P}\infty$ is smooth and brilliant, passing into $\frac{4}{3}\breve{P}\infty$ or $0P$ by a roughened line. $\frac{4}{3}\breve{P}\infty$ and $0P$ are usually rough through minute irregularities bounded by crystal planes. The base is usually very narrow through the predominance of the brachydomes, the pyramidal planes and the macrodome are quite insignificant when present at all, and $\infty\breve{P}\infty$ is occasionally present as a small, smooth face. No indications of hemimorphism are noticeable, although the faces of opposite ends are seldom symmetrically developed.

Some of the crystals have a decided greenish tinge, although many are colorless.

TOPAZ FROM DEVIL'S HEAD MOUNTAIN.—The country embracing Devil's Head Mountain is composed chiefly of the same granite which has been described in its occurrence near Pike's Peak, and it contains similar druses of microcline, smoky quartz, and other minerals. The topaz found here is the most noteworthy crystallized species, some of the specimens found being probably the best yet discovered in the United States. The discoverer, Mr. W. B. Smith, now assistant in the Rocky Mountain division of the Survey, has given us a few notes on the manner of occurrence and associations of the topaz, which are appended to this description, p. 73.

In the American Journal of Science for December, 1883, Rev. R. T. Cross, of Denver, published a note announcing the discovery of this locality by Mr. Smith. The specimens obtained since that time are much superior to those first found, though comparatively few in number.

Specimens from Devil's Head have found their way into various mineral collections of the country, and as the most noteworthy crystals passed through our hands we are able to give some details. All are colorless or faintly wine-colored and very clear within, though marred by more or less roughened surfaces, often stained by oxide of iron which penetrates fissures. Many fragments are sufficiently clear for cutting.

Three especially fine crystals have been obtained. Of these the one with the most polished surfaces, and hence the clearest, weighs 3.5 ounces, measuring $\breve{a}:\bar{b}:\dot{c}=4.4:4.9:3^{cm}$. The faces ∞P, $\infty \breve{P}2$, $4\breve{P}\infty$, $\frac{4}{3}\breve{P}\infty$, $0P$, $\frac{2}{3}\bar{P}\infty$, P, and $2P$ are quite well developed, while $\infty \breve{P}3$, $\infty \breve{P}\infty$, $2\bar{P}\infty$, and $\frac{2}{3}P$ are less prominent or not present in full quota. But one termination has definite faces.

The second crystal weighs 5.5 ounces, and measures $\breve{a}:\bar{b}:\dot{c}=3.7:5.5:4.6^{cm}$. Clear with dull surfaces. One termination has large $0P$, with a very symetrical development of the faces mentioned above and $2\breve{P}\infty$. A second termination is formed by one large undulating face, corresponding to $\frac{2}{3}P$, with $0P$ and single faces of $4\breve{P}\infty$ and $2P$.

A third crystal weighs $6\frac{3}{4}$ ounces and measures $\breve{a}:\bar{b}:\dot{c} = 4.2:5.3:4.5^{cm}$. It has rather dull surfaces but is clear within, and has a distinct wine color. One termination is quite symmetrical, showing the planes named.

A number of the smaller crystals are very clear and transparent, with beautifully polished surfaces, although it is seldom that all are smooth.

Nearly all crystals from Devil's Head, Crystal Park, and many from Florissant, have been found detached, some being badly broken. The same is true of a large portion of the crystals of the accompanying minerals. Movements of the whole mountain mass, as in folding or faulting, have probably caused this detachment and fracture of the crystals. Particularly noticeable with the topaz, though also observed on smoky quartz, is the fact that all these old fracture planes are healed over, so to speak, and are now covered by drusy surfaces caused by little prominences which are bounded by glistening crystal faces. An examination shows that pyramidal planes of both orders are the most common, the little elevations resembling those upon $2\breve{P}\infty$ above described. When the fractured plane is parallel 0P there are usually a great number of the pits or etching figures also previously noticed.

APPENDIX.

NOTES UPON THE OCCURRENCE OF TOPAZ AT DEVIL'S HEAD MOUNTAIN, BY W. B. SMITH.

The name "Devil's Head" was applied many years since to a jagged and precipitous mass of granite, rising to a height of 9,348 feet, in the Colorado range, some 30 miles north of Pike's Peak. This is the name by which it is still known locally, though upon Hayden's Atlas it is called "Platte Mountain."

The granite forming the mountain is similar to that near Pike's Peak, and the minerals found occur in cavities or pockets as in the latter region. No extensive pockets of amazon stone, smoky quartz, etc., have been found, but a few smaller ones contain a noteworthy association of species.

TOPAZ.—The pocket in which the topaz was found is of irregular shape, being about 50 feet long, from 2 to 15 feet wide, and averaging 4 feet in depth. Owing to the disintegration of the rock at the surface many of the crystals had been carried in the *débris* to a considerable distance down the mountain side, and were badly worn and broken.

The topaz occurs in isolated and usually loose crystals, surrounded by distorted quartz crystals, of smoky and reddish shades—frequently the exact color of the topaz—light green microcline, mamellary radiations of albite, cleavage masses and compact nodules of mica—probably muscovite, although sometimes much altered from the original substance. Also, more rarely, cassiterite, goethite, orthite?, fluorite and kaolinite occur. Much of the topaz is reddish, though wine-yellow, milky blue, and colorless crystals were found.

All the crystals attached to the gangue were more or less decomposed, a kaolin-like substance being the result. Frequently the terminal planes and a part of the prism would be found protruding from the rock unaltered, while the remainder of the crystal, running into the albite, would be composed of alternate layers of topaz and kaolin. More frequently, however, the kaolin, instead of being parallel to the cleavage planes, occupied curved fissures running irregularly through the topaz.

MICROCLINE.—This mineral in simple crystals was the common species in the pocket. Some were very large, measuring 18 inches across. They were usually badly fractured and fell in pieces on being removed. The base, 0 P, of each crystal has a curious appearance, owing to the angular elevations and depressions that compose the surface, looking not unlike oriental characters cut in relief.

CASSITERITE.—Twenty-five or thirty small, irregularly-shaped masses of this mineral were found embedded in massive albite or quartz. A few rude crystals were obtained, one being a little less than an inch in diameter. Only the pyramid is developed. No cassiterite was found outside of the topaz-bearing cavity.

FLUORITE.—In the adjacent region a number of interesting crystals of the chlorophane variety of fluorite were found in a small pocket of microcline and smoky quartz. The most perfect crystal is a cubo-octahedron, with every face well developed. It was found lying loose in the cavity and the surface is rough. The color is of a greenish tinge outwardly, with an included cube of dark purple.

III.—ON THE LUSTRE EXHIBITED BY SANIDINE IN CERTAIN RHYOLITES.

By WHITMAN CROSS.

The sanidines of two rhyolites in Colorado, examined by the writer, possess a remarkable lustre which is, as far as he can ascertain, unlike anything previously described by any other observer. One of these cases has already been briefly noticed in the American Journal of Science for February, 1884. The discovery of a second instance of this same lustre, and the results of a comparison with earlier descriptions of lustre and color in feldspar, render a fuller treatment in this place desirable.

SANIDINE IN RHYOLITE FROM CHALK MOUNTAIN.— The rhyolite containing the lustrous sanidine occurs in a massive body forming the greater part of Chalk Mountain, situated upon the continental divide at the headwaters of the Arkansas, Ten Mile, and Eagle Rivers, in central Colorado. It is of the type recently defined as nevadite by Messrs. Hague and Iddings,[54] and may be characterized as a porphyritic rock, showing large glassy sanidine and many smoky quartz crystals embedded in a grayish ground mass, which appears under the lens to be evenly granular, and is really so, with the exception of isolated glass particles revealed by the microscope. Biotite is but sparingly present. This nevadite is one of the most beautiful of rocks, owing to its abundant smoky quartz crystals and to the lustrous sanidines about to be described. Chalk Mountain lies upon the boundary between the geological maps of the Mosquito range and of the Ten-Mile mining district, which are soon to be published, with monographic reports, by the U. S. Geological Survey. In both of these works the manner of occurrence and the characteristics of the rock will be fully given.

Many crystals of sanidine in the nevadite exhibit in certain positions a delicate or brilliant satin-like lustre. If examined with the aid of a lens a faint play of very delicate colors is seen, while the crystal seems white and opaque when looking down upon the lustrous surface in such a direction that the lustre itself does not appear. The position of the lustrous plane is readily seen to be near that of the orthopinacoid, and the extent of the deviation from it is plain when a crystal twinned according to the Carlsbad law is observed. By facing the light and revolving such a crystal about its orthoaxis it is found that the lustrous planes of the two halves are not coincident, but are inclined at approximately 20° to each other, while evidently lying in or very near the orthodiagonal zone.

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[54] Am. Jour. Sci., III, XXVII, 461, 1884.

On examining the larger crystals a cleavage parallel to the plane of lustre is evident, and if an isolated fragment be fractured by a sharp blow upon the predominant brachypinacoid many flakes are produced, some of which are parallel to 0P, while others are parallel to the lustrous surface. Those parallel to 0P exhibit under the microscope a very fine striation at right angles to the frace of $\infty P \breve{\infty}$, while optical action is normal. The flakes parallel to the plane of lustre are found to be made up of extremely thin plates, usually rectangular through the development of cleavages parallel to 0P and $\infty P \breve{\infty}$. If but a few of these plates overlie each other, delicate variegated colors appear in ordinary light. By increase in the number of plates the flake becomes dull white and opaque. The phenomena are very plainly the familiar ones produced by polarization and interference of light in traversing a series of thin plates. Transmitted light is soon wholly extinguished by a sufficient increase in the number of plates, and reflected light produces the lustre seen.

A parting parallel to this plane can be easily produced with a knife-blade in those crystals having a very bright lustre. The separation is as sharp and perfect as that parallel to any cleavage plane of the crystal. By sections parallel to $\infty P \breve{\infty}$ the position of the plane with reference to the axes $\breve{a}$ and $\dot{c}$ is readily determined with approximate correctness; but the most satisfactory, and probably the most accurate, measurements were obtained in the following manner:

At one point in the mountain the nevadite, here unusually coarse-grained, was found to contain many small round or irregular druses lined by minute but perfect transparent crystals, chiefly of sanidine and quartz. The quartz crystals are for the most part simple dihexahedrons; the sanidines thin tablets, which are almost invariably Carlsbad twins, with prominent development of the clinopinacoid. Such crystals examined under the microscope, as they lie upon the predominant pinacoidal face, afford a means of determining approximately the position of the plane parallel to which the parting referred to takes place.

Fig. 13 of the plate represents one of these crystals, a normal Carlsbad twin, with a third and smaller plate, also in twin position. The faces shown in profile are ∞P, 0P, $P\bar{\infty}$, and $2P\bar{\infty}$. From all the outlines and from basal cleavage or irregular fissures run very fine dark lines, in uniform direction for each individual of the twin, and penetrating varying distances into the crystal. This undoubtedly represents an incipient stage of that parting which, in some crystals of the rock, occasions the brilliant lustre, for these dark lines do not represent needles of any mineral substance, but air films, upon the fissures, showing the extent to which actual parting has taken place in the direction indicated in the remainder of the crystal by the fine, clear striation. As seen from the figure, the position of the surface is that of a positive hemi-orthodome, for the cleavage plates of large crystals show the plane to be at right angles to the clinopinacoid. The mean of a number of measurements in different parts of the crystal places the inclination of the plane thus indicated to the vertical axis at 8° 40′. Assuming the axial ratio—

$$\grave{a}:\bar{b}:\acute{c} = 0.653:1:0.552 \text{ and } \beta = 64.$$

as determined by Strüver[55], for free crystals of sanidine, the face corresponds closely to $\frac{15}{2}\,P\,\ddot{\bar{\infty}}$. This would require an angle of 72° 40′ with the basal plane, while that measured in the crystal figured was 72° 53′. Of course this cannot be regarded, under the circumstances, as anything more than an approximate determination.

The lustre as thus far described is found chiefly in the sanidines of the coarser-grained modifications of the rock. Some of the crystals do not exhibit the phenomenon distinctly, and in those of the finer-grained portions of the mass it is commonly not visible at all. Yet, thin sections of such varieties do sometimes show a pale, delicate, bluish color in the sanidines, which is like that often seen in labradorite. By close examination of sections parallel to the plane of the satiny lustre it is frequently found that there are clear and transparent portions which do not exhibit the bright lustre, but if the light be properly guarded a faint bluish color is seen in these clear portions simultaneously with the satin-like lustre in the remainder. After the connection has thus been established it becomes easy to see, in most cases, that the blue color, seen only in clear and transparent crystals, appears upon the same plane which in other cases shows the satiny lustre.

SANIDINE IN RHYOLITE FROM RAGGED MOUNTAIN.—Since the appearance of the article describing the lustre of the Chalk Mountain sanidine, another and even more striking instance has been brought to the notice of the writer, through his friend Mr. R. C. Hills, of Denver, who presented him with a sanidine crystal from the rhyolite of Ragged Mountain, Gunnison County, Colorado, in which the satiny lustre is very marked. The crystal in question was several inches in length parallel to the clinoaxis, and has a square prismatic form in that direction, through the predominant and equal development of $\infty P \grave{\infty}$ and 0P. The brilliant, satiny lustre is exhibited in all its beauty when these elongated crystals are fractured transversely, and in the crystal seen the fracture is parallel to the lustrous plane itself. According to Mr. Hills, this is commonly the case, and large masses of the rock often show numerous square sections, reaching 2–3 inches in diameter, each possessing the lustre very distinctly.

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[55] Cited by Tschermak, Lehrbuch der Mineralogie, 1883, p. 455.

plained the blue color as due to polarization from thin plates, the yellow and red as caused by numerous included lamellæ and microlites of mineral substances, while the green and violet shades are thought to be the result of a combination of the blue with the yellow or the red. Reusch states, as mentioned above, that the undeveloped cleavage in labradorite does not correspond in position to that in adularia, being near the brachypinacoid and variable in different specimens.

From the above it seems quite possible that the rectangular bodies thought by Brewster to be the cause of the bluish color may have been the equivalent of those seen in the sanidine, which indicate the beginning of the actual parting in the direction of the latent cleavage.

LUSTRE UPON OTHER SANIDINES.—In the Microscopical Petrography of the Fortieth Parallel (p. 83), Professor Zirkel mentions a "superb blue color" as characteristic of the small sanidines in a rhyolite from Ohataya Peak, Pah Ute Mountains, Nevada. It is also visible in various rhyolites east of the point named. The cause of the color is thought unexplainable, for "no strange particles can be detected, neither needles, nor plates, nor grains, nor a dust-like powder, nor glass or fluid inclusions."

An examination of these rhyolites by the writer indicates clearly that this phenomenon is simply another instance of that which has been described. The intensity or brilliancy of the color exhibited in some of these rocks is quite striking.

CONCLUSION.—The phenomenon which has been described does not seem comparable with any hitherto recognized property of crystals. It seem incorrect to speak of it as "cleavage," for that internal structure manifested by the fine basal cleavage of this same species is accompanied by no such optical action; nor can the writer recall any such combination in any other mineral. This lamellar structure is to be considered as another of those physical characteristics of minerals, such as cleavage, fracture-figures, "*gleitflächen*," etching-figures, twinning produced by pressure, etc., which will doubtless remain unexplained until the molecular constitution of crystallized bodies is made clear.

IV.—AN UNUSUAL OCCURRENCE OF TOPAZ.

By WHITMAN CROSS.

The nevadite of Chalk Mountain, which was described in the preceding section, contains in its small drusy cavities another mineral of decided interest besides the sanidine. Accompanying the quartz and sanidine in the cavities are minute leaflets of biotite, a few ore grains, and, in a few druses only, very perfect crystals of colorless transparent topaz. Usually but a single crystal of topaz is present in one of the druses, and that is larger and more perfect in development than any other. The topaz is attached directly to the walls of the cavity and often bears small tablets of sanidine upon it. The crystals which can be recognized as topaz vary from 0.5^{mm} to 3^{mm} in length, but it seems quite probable that there are some smaller ones indistinguishable from quartz.

The determination as topaz rests upon the crystalline form which is very distinct and is that of common topaz. One crystal measuring 3^{mm} in length and 1^{mm} in thickness was removed from the rock and its angles measured with a Fuess reflection goniometer. This crystal presents ∞P, $\infty \breve{P}2$, and $2\breve{P}\infty$ as the dominant forms; 0P is a narrow face and $4\breve{P}\infty$, $2\bar{P}\infty$, 2P, and P are minute, but very distinct. The angles measured are as follows:

	°	′
$\infty P \wedge \infty P$	124	16
$\infty \breve{P}2$ over $\infty \breve{P}\infty$	93	7
$0P \wedge 2\breve{P}\infty$	136	30
$0P \wedge P$	134	11
$0P \wedge 2P$	115	55

$2\bar{P}\infty$ appears as a very narrow face in the zone of 2P to 2P. This is the usual habit, with the occasional addition of $\infty \breve{P}\infty$ and a more prominent development of 0P. This crystal is also imperfectly terminated at the attached end, showing $2\breve{P}\infty$ most prominently, with $4\breve{P}\infty$ and 2P also recognizable, and there are no signs of hemimorphism.

In some druses all crystals are thinly coated by a black incrustation which seems to be pyrolusite.

So far as I can ascertain, all previously known and described occurrences of topaz are in granite, gneiss, or some other member of the series of metamorphic or crystalline schists. In the present case topaz is found in an eruptive rock, probably of early tertiary age, while the appearance of the associated minerals certainly suggests that they may all be sublimation products, though it is not capable of direct proof. The sanidine crystals from the druses, examined microscopically, contain gas inclusions, while neither fluid nor glass inclusions were seen.

V.—ASSOCIATED RARE MINERALS FROM UTAH.

By W. F. Hillebrand.

In the American Eagle mine, Tintic mining district, Utah, occur, in intimate association, several minerals, the majority of which, it is believed, are new to the American continent. All the specimens examined were obtained from an ore-heap at the works of the Boston and Colorado Smelting Company, near Denver, where they were first observed and their probable identity established by Mr. Richard Pearce, metallurgist to the above company. More detailed examinations were made in the laboratory of the Survey at Denver, as opportunity offered, in compliance with a desire expressed by Mr. Pearce.

OLIVENITE.

Recognizable by its dark olive-green and wood-brown color, and by its crystal form, is olivenite, occurring in a mixture of various brown and yellow oxygen salts of iron, copper and calcium. The only planes observed, according to Mr. Whitman Cross, belong to the prism and brachydome. While fine crystals are not of infrequent occurrence, the major part of the mineral appears in that characteristic brown, compact, fibrous state to which it owes its old name of wood-copper. The amount of crystallized material available sufficiently pure for a satisfactory analysis was very limited on account of the firm adherence of small green hemispheres of conichalcite on many of the crystals. Analysis gave the following results:

	XL.
CuO	55.40
As_2O_5	40.05
P_2O_5	0.06
H_2O	3.39
Fe_2O_3	0.25
CaO	0.16
ZnO	Trace.
Quartz	0.40
	99.71

The ferric oxide of the analysis was derived from a little adhering hydrated cupri-ferric arseniate and the calcium and zinc [redacted] tached conichalcite. The oxygen ratio for CuO : As_2O_5 ([redacted]

4.00 : 5.00 : 1.08, instead of 4 : 5 : 1 required by the formula $Cu_3As_2O_8+H_2CuO_2$.

CONICHALCITE.

Covering the surface of often large pieces of more or less soft and friable mixed arseniates, sometimes uniting to form a complete coating, are innumerable beautiful emerald-green semi-translucent globules, averaging three-fourths of a millimeter in diameter and showing distinct radiate structure when broken. Notwithstanding the considerable amount of material from which to select, the obtaining of perfectly pure material in sufficient quantity for analysis was impossible without devoting several days to the work, in consequence of the firm adherence of gangue to the flattened base of the globules and of the fact that the nucleus of each globule usually consisted of some of the same soft gangue matter. The material analyzed was so small in quantity, therefore, that the analytical results can lay no claim to the highest degree of accuracy, especially as all estimations had to be made upon the same portion. No specific gravity determination was attempted for this reason, and also because there were no means of determining the corrections to be made for small amounts of impurities other than quartz.

	XLI.	Conichalcite from Spain.
CuO	28.68	31.76
CaO	19.79	21.36
MgO	0.54	
ZnO	2.86	
Ag	0.30	
As_2O_5	39.94	30.68
P_2O_5	0.14	8.81
V_2O_5		1.78
H_2O	5.52	5.61
Fe_2O_3	0.36	
CO_2	*0.97	
Quartz	0.90	
	100.00	100.00

* By difference.

The ferric oxide was derived from attached gangue. The carbon dioxide was probably combined with lime, since a temperature was required for its expulsion higher than that at which all the water escaped, the latter having been estimated by direct weight. Part of the water seemed to escape at a much lower temperature than the remainder. The silver is not a constituent of the gangue, since none could be found in the latter underlying the green coating. It is not present as chloride, for nitric acid readily takes it all into solution; nor could any native silver or sulphide be detected. The only conclusion to be drawn is that it exists in the mineral in an oxidized state, presumably as silver arseniate.

In appearance and composition this mineral resembles no other than conichalcite, found hitherto only in Andalusia, Spain, and represented by a single analysis in Dana's System of Mineralogy, p. 563 (quoted above for the sake of comparison). It will be noticed that vanadium is wanting (it was specially looked for) in the mineral from Utah, and phosphorus nearly so; while zinc, which was not a constituent of the Spanish mineral, here replaces apparently some copper.

Allowing for the CO_2 its equivalent of CaO, the oxygen ratio is as follows:

$$\begin{array}{lll} RO & : As_2O_5\ (P_2O_5) & : H_2O. \\ 1.00 & : 1.18 & : 0.41. \quad \text{or} \\ 4.00 & : 4.72 & : 1.64. \end{array}$$

instead of 4 : 5 : 1.5 required by the supposed formula $(Cu, Ca)_3\ As_2O_8 + H_2CuO_2 + \frac{1}{2}H_2O$.

Heated in any manner before the blow-pipe most violent decrepitation ensues, the entire fragment flying into fine powder. In a closed tube, after decrepitation has ceased, the particles by gentle tapping may be made to collect at the bottom as a brown-black spongy mass of great volume. This collected on a loop of platinum wire fuses before the blow-pipe, at first with a pale bluish coloration of the flame. This behavior accords in a measure with that mentioned in Dana's System of Mineralogy (*loc. cit.*).

CHENEVIXITE.

Thickly scattered in irregular patches throughout some portions of such ore as occurs in hard lumps, giving to a broken surface a mottled appearance, is a compact greenish opaque body, with little or no lustre, which corresponds in composition very well with chenevixite from Cornwall, as represented by one of the two analyses in Dana's System of Mineralogy, p. 583. The hardness, however, is lower, being 3.5 instead of 4.5, as there given. The color is an olive-green, sometimes shading away into a greenish yellow after exposure. The fracture is subconchoidal.

	XLII.			Chenevixite from Cornwall.
	a.	*b.*	Mean.	
CuO ...	26.41	26.21	26.31	31.70
CaO ...	0.44	....	0.44	0.34
MgO ...	0.16	....	0.16	....
Fe_2O_3 ..	27.87	....	27.37	25.10
Al_2O_3 ..	0.66	....	0.66	....
As_2O_5 ..	35.08	35.20	35.14	32.20
P_2O_5 ...	....	....	....	2.80
H_2O ...	9.41	9.25	9.33	8.66
Quartz	0.40	....	0.40	....
	99.93	....	99.81	100.80

The analysis was made upon air-dried powder, since the latter loses about 0.75 per cent. of water even over sulphuric acid, which loss becomes slightly greater at 100° C., and continually increases as the temperature rises. The oxygen ratio is—

$$\begin{array}{lll} RO + R_2O_3 & : As_2O_5 & : H_2O. \\ 6.00 & : 5.23 & : 3.55., \end{array}$$

while that of the above-quoted analysis of the Cornwall mineral is 6:5.35:3.30 instead of 6:5:3, as assumed most probable. The material now analyzed cannot with any certainty be regarded as pure, hence the deviation from this theoretical ratio is not of great importance.

Before the blow-pipe the mineral from Utah differs from that from Cornwall, in that it does not usually decrepitate, while in other respects the behavior is identical; it fuses readily, gives off arsenical fumes, and leaves a black magnetic scoria.

Both chenevixite and conichalcite appear to be generally regarded as doubtful species, for their names do not figure at all in some of the best mineralogical works, but it can hardly be questioned now that they represent definite species whose precise nature, however, is yet a matter for further investigation to reveal.

A HYDROUS CUPRI-CALCIUM ARSENIATE.

In rare instances, fine silky white needles have been observed, chiefly on conichalcite, but in such small quantity that the only data as to their composition are the following determinations made by Mr. Pearce on less than a centigram of material:

CaO	31.5
As_2O_5	38.6
CuO and H_2O*	29.9
	100.0

* By difference.

The copper estimation was a failure, but the percentage of CuO was judged to be fully 20 per cent. The composition would then seem to be near that of conichalcite with the proportions of CuO and CaO reversed, but in view of the wide limits to be allowed for possible error in the analysis, further comment is useless.

JAROSITE.

Jarosite in fine transparent brown crystals was observed by Mr. Pearce on a few specimens of ore. The identification rests upon partial chemical analysis, and more fully upon angle measurements by Mr. Whitman Cross.

THE MASSIVE ORE.

With jarosite is completed the list of probably distinct species, as far as observed, with the exception of one or two others present in too small quantity for even qualitative identification. There are, however, certain characteristic components of the ore which seemed to merit examination.

A portion of the ore is a brown substance, showing nodular forms and a granular surface when broken and of considerable hardness owing to disseminated quartz. Analysis furnished the following results:

	XLIII.
Fe_2O_3	44.22
Al_2O_3	0.48
CuO	1.30
CaO	1.33
MgO	0.10
K_2O	1.72
Na_2O	0.46
As_2O_5	20.01
SO_3	6.66
H_2O	11.02
Quartz	12.00
	99.30

These figures probably represent a mixture of a hydrated ferric-alkali sulphate (perhaps jarosite), and one or more hydrated arseniates.

In places it passes gradually into a brilliant black substance, closely resembling jet, and possessing conchoidal fracture, difficult to extract even in very small quantity, but having, according to Mr. Pearce, the following composition:

Fe_2O_3	41.47
CuO	4.88
CaO	7.27
As_2O_5	27.65
Ign	18.49
	99.76

It was subsequently ascertained that the loss on ignition represents SO_3 as well as H_2O, hence it is useless to attempt the construction of a formula.

Filling interstices between the nodular forms of the brown mixture above described and occurring as an irregular coating on much of the ore, there is a soft powder of a bright straw color of which the average composition is as follows:

	XLIV.
Fe_2O_3	37.84
PbO	13.74
CuO	2.33
K_2O } Na_2O }	*3.93
As_2O_5	12.22
P_2O_5	0.40
SO_3	16.85
H_2O	9.39
Quartz	3.30
	100.00

*By difference.

The resemblance to certain alteration products of galena and pyrite found in several of the Leadville mines is striking, and, like some of these, it seems to be a mixture of lead sulphate, jarosite, and hydrated ferric arseniate.

All of the above-described minerals and mixtures, with exception of crystallized jarosite, may sometimes be observed on one and the same piece of ore. It is not improbable that further investigation at the mine itself might bring to light still other minerals belonging to the group of hydrous arseniates.

In this connection it may be mentioned that Mr. Pearce has identified pseudomalachite occurring with hübnerite (see p. 96) from near Philipsburg, Montana Territory. According to Mr. Pearce's analysis it contains CuO 62.56, P_2O_5 20.10, H_2O 17.34 (by difference).

VI.—MISCELLANEOUS MINERAL NOTES.

By W. F. HILLEBRAND.

LÖLLINGITE.

OCCURRENCE.—The cobaltiferous and nickeliferous variety of löllingite which is to be described occurs at the head of Brush Creek, Gunnison County, Colorado. It has been found in the Luona mine at the western base of Teocalli Mountain, and in the American Eagle and Horace Porter mines on White Rock Mountain. The peculiar ore bodies of which the löllingite forms a part are irregular masses, the relations of which are not yet understood. The investigations of the United States Geological Survey, now in progress in Gunnison County, include the area of Brush Creek, and these interesting bodies will be carefully studied.

At the Luona mine, according to Mr. J. G. Ridgley, of Denver, the löllingite is associated with native silver, proustite, argentite, pyrargyrite, chalcopyrite, galena, siderite, barite, and calcite, the last three composing the gangue. Much of it is decomposed, forming secondary oxidized products, most conspicuous among which is erythrite. At the other localities smaltite is a common associate. The smaltite analyzed by Dr. W. M. Iles (Am. Jour. of Sci., III, XXIII, 380, 1882) was probably from one of the mines on White Rock Mountain.

DESCRIPTION.—The löllingite occurs in compact, massive form, and also embedded in barite or siderite, and presents a very striking appearance on fresh or newly fractured surfaces. There are seen embedded in the siderite and barite gangue, steely white forms, about one-eighth of an inch in diameter, of pronounced radiate structure, the longer radii protruding from the mass and giving the whole a beautiful stellate appearance. The star forms occur sometimes single, but more frequently joined together in greater or less number without losing in any marked degree the peculiar character of the individual. In some specimens the appearance approaches that of a dense, homogeneous mass, several inches in diameter, but even in the densest portions the radiate structure is generally distinctly discernible.

In order to discover, if possible, a clue to the crystallographic structure, and also to obtain material for analysis, specimens were treated with hydrochloric acid without previous crushing, whereby the siderite and the arseniates of iron, cobalt, and nickel were entirely dissolved. The löllingite remained quite black on all parts where the gangue had been eaten away, but surfaces of previous fracture retained their white color. The star like forms were then seen to be composed of a considerable number of long flattened ellipsoids, interpenetrating at a common centre in every direction. When one of these clusters was broken through, the star form appeared on the surface of fracture. The aggregates were joined together loosely, now that the cementing material had been removed, though frequently in large clusters of many hundreds of all sizes, from those visible only with the aid of a microscope to others an eighth of an inch or more in diameter.

A microscopical study of the finer part of the material liberated from its imprisonment in the gangue, and broken off from the larger pieces during the treatment with acid and subsequent washing, furnished the solution to the question as to what was the crystallographic form of the flattened ellipsoids composing the aggregates, and the law of the twinning. The fundamental form is that of löllingite, showing only the prism and macrodome, as in Fig. 14.[58] Frequently these two forms are equally developed, producing a resemblance to a low pyramid of the tetragonal system. Very few even of the most minute crystals are perfect in form, and possessed of sufficiently smooth surfaces to allow of even approximate measurement under the microscope. Repeated attempts were made to get these in proper position under the instrument, but in only one case with comparative success, owing to their microscopic size. The angle of the prism was then found to be very nearly 122°, that given for löllingite being 122° 26′.

Parallel to the combination edge of the prism and macrodome there is almost always on the prism a striation (more coarsely marked the larger the crystal), caused by the alternate reproduction of the prismatic and domatic faces. Approaching the combination edge the reproduced dome face becomes relatively larger than that of the prism, the consequence of which is a gradual rounding of the corners and a contraction, and eventual disappearance of a distinct terminal dome, the result being, as represented in Fig. 15, an elipsoidal form with a slight ridge through the center representing a prism edge. Frequently the corners of a crystal, occupying the position of Fig. 14, appear as if modified by a brachydome, but no such form has been observed, the replacement being a straight serrated edge, caused by the same alternation of faces as in the case of rounded corners. Even where the macrodome is well developed it generally shows a continuation in some degree of the prismatic striation parallel to the same combination edge.

The first step toward the complex twin structure is the formation of a single twin, or, rather, trilling, by interpenetration of three single crystals having the basal section in common, and a face of the prism as composition face (Fig. 16). A basal section shows a six-rayed star, with angles of very nearly 60°, by microscopical measurement, between the axes of the rays. In the microscopic trillings one individual frequently predominates greatly in size over the other two, these appearing often as thin leaves, projecting but a short way out of the larger crystal. These trillings are finally found again interpenetrating, not according to any recognizable law, but seemingly in every direction, and in indefinite numbers, forming thus the complex aggregates first spoken of. All these stages of changes in form may be observed with great ease under the microscope, the very smallest crystals alone showing crystallographic faces well defined. As the crystals, single or twin, increase in size, the faces gradually grow more and more indistinct, and finally disappear entirely in consequence of increasing striation.

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[58] All the accompanying figures, with the exception of Fig. 14, were drawn by the aid of a camera lucida, and therefore make no pretensions to crystallographic accuracy. Fig. 17 is magnified about 15 diameters, the others from 40 to 150 diameters.

Notwithstanding repeated attempts, the basal cleavage mentioned in text-books as characteristic of löllingite could rarely be produced, and no cleavage in any other direction except in the case of the trillings. Here an individual frequently broke off at the line of union of the three; that is, in a plane parallel to the brachypinacoid.

Aside from the forms distinctly recognizable as löllingite are, however, others belonging apparently to two different minerals. The first of these became visible on dissolving the gangue, when there came to the surface of the acid and the water used for washing out the latter a great number of minute but brilliant metallic particles, which resolved themselves, under the loupe, but still better under the microscope, into thin leaves or blades, of which Fig. 17 represents one of the more perfect examples. Its forms appear to consist of two pinacoids of the rhombic system, one very broad, the other very narrow, and a terminal dome having an angle of almost exactly 90° by microscopical measurement. The faces are most brilliantly reflecting. Distinct cleavage was not observable. The second mineral, which is almost always microscopic in size, is represented in Figs. 18, 19, and 20. The prominent form is that of a lengthened prism with an angle of very nearly if not quite 90°. Repeated measurements gave values fluctuating between 88° and 92° as the extremes. It is terminated at right angles by a basal plane, the four corners of which are frequently replaced by faces which may be those of a pyramid or two domes, according as the habit is pinacoidal or prismatic. The cleavage is parallel to the base. Single crystals are rare, two or more being generally seen interpenetrating, as in Figs. 18 and 19, generally at an angle of 90°, or united, as in Fig. 20. In the latter figure only the outlines, not the faces, of the different horizontal individuals are shown; nor do the numerous vertical attachments present appear. Occasional instances of three prisms crossing at right angles like the axes of a rectangular system were observed, and also a single instance of the form represented in Fig. 21, where each of the arms showed a domatic face. The most striking feature of all but the last of these different forms is the invariable widening at the point of union or intersection, as shown in the figures.

CHEMICAL COMPOSITION.—Even an approximate separation of the last two minerals described, from each other and from the smallest löllingite crystals, was impossible, hence no conclusion could be reached as to their quantitative composition. Qualitative tests proved them both to be arseniates of cobalt, the square prismatic forms containing also iron and nickel. An incomplete quantitative test upon a mixture of these three minerals showed a much higher percentage of cobalt and nickel than the analysis of the pure löllingite.

Before the blow-pipe the löllingite furnished the reactions mentioned in the text-books, the residue after treatment with charcoal being infusible, strongly magnetic, and, furthermore, giving the characteristic reaction for cobalt with fluxes; soluble in nitric acid, giving a pink solution.

Of the analyses given below, XLV was made upon clusters of löllingite trillings, free, so far as could be determined by the loupe, from attached or penetrating blades or prisms of the other two minerals described. As a check a small quantity of the single crystals and trillings was picked out with the utmost care under the microscope and subjected to partial analysis (XLVI), no trace of foreign adherent matter being visible. The specific gravity of the material used for the first analysis was 7.335 at 14½° C. Correcting for one half per cent. of siliceous gangue of assumed specific gravity 2.65, the true specific gravity of the mineral becomes 7.400.

	XLV	XLVI
As	71.18	....
S	0.56	....
Bi	0.08	....
Cu	0.39	....
Fe	22.96	22.69
Co	4.37	4.20
Ni	0.21	0.19
	99.75	

The first of these analyses leads closely to the formula $Fe(Co, Ni)As(S)_2$, while XLVI shows beyond a doubt that both cobalt and nickel are constituents of the löllingite and not derived from attached crystals of either of the other minerals. The presence of cobalt recalls the glaucopyrite of Sandberger, though the antimony found in that mineral is here wanting. The peculiar comb-like excrescences described by him, indicating rhombic twinning by interpenetration, may be analogous in some degree to the twinned structure of the present mineral.

Some varieties of rhombic $CoAs_2$, all of which, according to Leroy W. McCay,[59] should be united under the name safflorite, present features remarkably like some of those herein described, notably as regards the tendency to form twins of interpenetration; and from the presence of cobalt it might be suspected that this mineral was rather to be considered as safflorite than löllingite. Its exceedingly high percentage of iron and high specific gravity, both greater than that of any safflorite yet examined, are not unimportant objections to this conclusion.

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[59] Inaugural Dissertation, Freiberg, 1883.

In the description of this mineral in the American Journal of Science, Vol XXVII, p. 354, through a misapprehension not to be explained in a few words, Sandberger is wrongly quoted as authority for the statement that the brachydome is characteristic of rhombic Co As_2. Attention was called to this error by Mr. Leroy W. McCay, who is inclined to consider the above-described mineral as safflorite. While acknowledging that through the elimination of the statement referred to, the main point there brought forward in favor of identity with löllingite was taken away, the evidence is by no means conclusive that the mineral should be classed with safflorite. Further examination, especially of a crystallographical nature, on both löllingite and safflorite, are necessary in order to settle this question. The mineral having been already described as löllingite, this name is here retained.

ZINCKENITE.

In the Brobdignag mine, Red Mountain, San Juan County, Colorado, occurs a massive gray mineral showing greasy metallic lustre, without apparent crystalline structure, but to all appearances of complete homogeneity; of specific gravity 5.21 at 18° C. and hardness 3–3.5, which upon analysis was found to be an arseniferous zinckenite, this being, it is believed, the first observed occurrence of the mineral in the United States. Besides the usual blow-pipe reactions for zinckenite, including violent decrepitation, there appear those for arsenic, preceded in the closed tube by a light sublimate of sulphur. The results of analysis are:

	XLVII.	
	a.	*b.*
Sb	35.00	....
As	5.64	5.59
Pb	32.77	32.79
Cu	1.20	....
Ag	0.23	....
Fe	0.02	....
CaO	0.31	....
K_2O Na_2O	0.45	....
S	22.50	22.50
Gangue	0.59	....
	98.71	

The atomic ratio is, for

$$(PbCu_2Ag_2) : (Sb_2As_2) : S$$
$$1.00 : 1.09 : 4.11.$$

While this is close enough to the theoretical ratio 1:1:4 to establish the probable formula PbS,Sb_2S_3, the result was not such as the care expended on the analysis warranted, supposing that no impurities were present. Calculation shows that while the antimony and arsenic taken together are in excess of the amount required for lead, copper, and silver, the sulphur falls short by half of one per cent. The actual deficit in the latter amounts, however, to about one per cent., for it was found that about half of one per cent. existed in the free state and could be extracted by carbon-disulphide. The only explanation of these contradictory circumstances was to be sought in the presence of oxygen salts, which would at the same time account for the difference between the sum total of the analysis and 100.

Ammonium acetate failed to extract any lead sulphate, but nevertheless pure water extracted a not inconsiderable quantity of soluble matter, even when the digestion was carried on in an atmosphere of carbonic acid. The filtrate showed neither acid nor alkaline reaction toward litmus paper. Silver nitrate produced no precipitate whatever, thus showing the absence of soluble chlorides or sulphides; but hydrogen sulphide threw down a copious orange colored precipitate of antimony trisulphide and the corresponding arsenic compound, entirely free from lead. Barium chloride produced a slight precipitate of barium sulphate. The antimony consequently existed in solution in an oxidized state—that of trioxide—as shown by evaporating some of the original solution with hydrochloric acid and adding potassium iodide. The manner of combination was not ascertained, but from the presence of alkalies this seems pretty certainly indicated. The salts, whatever they may be, are not very readily solub'e, for six digestions with warm water in an atmosphere of carbonic acid were insufficent to complete the extraction. The sulphur trioxide found was probably combined with lime.

These experiments show that a large part of the apparent loss in the analysis is to be made up by oxygen, which, by requiring a considerable proportion of antimony, arsenic, and sulphur for combination, brings the ratio of the elements actually constituting the zinckenite very near that required by theory. They also show that the specific gravity given above, even were it corrected for quartz, is too low. Suitable corrections for quartz, free sulphur, and soluble salts would undoubtedly increase the specific gravity to the figure given in text-books, *i. e.*, 5.3–5.35.

The above method of examination and its results have been dwelt upon somewhat in detail, because they show so clearly that apparent homogeneity in the case of non-crystallized metallic sulphides is no criterion of their purity, and also because thereby is indicated a possible way of reconciling with some definite formula the results of many analyses, especially of massive uncrystallized metallic sulphides, like the one here described, whose position in a system of classification might otherwise be impossible of precise determination. (See also Guitermanite, p. 106.)

COSALITE.

In the collection of the Colorado Scientific Society are a few specimens of a mineral from the Comstock mine, near Parrott City, La Plata County, Colorado, presented by Mr. R. C. Hills, according to whom it occurs in a quartz vein associated with pyrite, sphalerite, a telluride of unknown composition, though probably sylvanite, and native gold. In the specimens examined it appears in irregular masses of small size, rarely an inch in length, and generally much smaller, without cleavage or recognizable crystalline structure except for an occasional faint indication of fibrous texture on fractured surface. The fracture is irregular; color, grayish white, but pale yellow on exposed surfaces; hardness, about 3.5; specific gravity undetermined.

The outer zone of the small bodies spoken of is found on close examination to be a mixture of two or more minerals, among which minute grains of pyrite were alone recognizable. Sufficient material was, however, obtained for analysis, free from all impurity, except a little pyrite and 1.29 per cent. of insoluble gangue. This afforded the following reactions: In closed tube, sublimate of sulphur; in open tube, formation of sulphur dioxide; on charcoal, fusible, giving reactions for lead, bismuth, silver, and copper; soluble in chlorhydric and nitric acids, in the former with precipitation of silver chloride.

The analysis, after deduction of the gangue, gave these results:

	XLVIII.*
Bi	42.93
Ag	8.43
Cu	7.50
Pb	22.49
Fe	0.70
Zn	Trace.
S	17.11
	99.16

* The following atomic weights are used: Bi. 208, Ag. 108, Cu. 63.4, Pb. 207, Fe. 56, S. 32.

Allowing for the iron and a proportionate amount of sulphur as pyrite, the atomic ratio deduced from the above is:

$$\begin{array}{ccccc} R & : & Bi_2 & : & S \\ 2.00 & : & 1.00 & : & 4.94 \end{array}$$

showing the general formula for the mineral to be $2\,RS+Bi_2S_3$, wherein R represents Pb and the double atoms Ag_2 and Cu_2. The ratio of $Ag_2+Cu_2 : Pb$ is 1 : 1.11.

Although copper was absent, and but 2 per cent. of silver present in the mineral originally described by Genth as cosalite, it does not appear advisable, in the absence of any data as to the crystallographic form, to consider this a distinct species, but to class it, as has been done with bjelkite, under cosalite.

HÜBNERITE.

In the collection of the Colorado Scientific Society are specimens of hübnerite from the Royal Albert vein, Uncompahgre district, Ouray County, Colorado.

The mineral occurs in long flattened crystals vertically striated, imbedded in quartz, but none sufficiently well formed for measurement could be extracted; in fact, definite faces are rarely visible, though two prisms and the orthopinacoid have been observed. The lustre is subvitreous to resinous, and the color brownish black to pale yellow in very thin crystals. In transmitted light the color is ruby red to yellow, slightly tinged with green when the thickness is not too great. Extinction takes place parallel to the vertical axis in a plate parallel to the orthopinacoid, and at an angle of 19° to 20° to the same axis in a cleavage section parallel to the clinopinacoid, as observed by Des Cloizeaux for wolframite. In the plates parallel to the orthopinacoid a tendency to cleave at right angles to the clinopinacoid and also at angles approximating 61° and 68° to the same face was observed. The specific gravity at 24° C. is 7.177, and the composition as follows:

	XLIX.
SiO_2	0.62
Nb_2O_5 (?)	0.05
WO_3	75.58
MnO	23.40
FeO	0.24
CaO	0.13
	100.02

Which agrees very closely with that required by theory for the formula $MnWO_4$.

This mineral is also found in a mine near Phillipsburg, Montana, according to Mr. Richard Pearce. The specimens in the collection of the Colorado Scientific Society show large flattened crystals of imperfect form in quartz. Mr. A. H. Low, chemist at the Boston and Colorado Smelting Works, has analyzed the mineral approximately and found:

WO_3	74.82
MnO	25.00
FeO	0.06
	99.88

Other localities of occurrence in Colorado are Jamestown, in Boulder County, and near Silverton, in San Juan County.

BINDHEIMITE.

A specimen of bindheimite from a claim near the Bertrand mine, Secret Cañon, Nevada, came into possession of the Colorado Scientific Society, and was analyzed in the laboratory of the Survey. The specimen was compact and devoid of crystal form, except for a few minute crystals impossible of identification. The color, in general a yellowish green, was in places lemon yellow. The specific gravity at 19° C. was 5.01, after allowing for 4.59 per cent. of quartz of 2.65 specific gravity, and 20.33 per cent. of cerussite of specific gravity 6.5. The following are the results of analysis:

	I.		
	a.	*b.*	Mean.
PbO	49.68	49.32	49.50
CuO	0.58	0.59	0.58
ZnO	0.17	0.19	0.18
CaO	0.66	......	0.66
MgO	0.03	......	0.03
K_2O	0.14	......	0.14
Na_2O	0.21	......	0.21
H_2O	5.86	5.87	5.86
Sb_2O_5	35.18	35.21	35.20
Fe_2O_3	0.09	......	0.09
Ag	0.29	......	0.29
CO_2	3.35	3.36	3.35
Quartz	4.59	......	4.59
	100.83		100.68

Of the water 1.95 per cent. escaped over sulphuric acid, and a further 0.70 per cent. at 100° C. The oxygen ratio derived from the above, excluding $PbCO_3$, Ag, and Fe_2O_3, is:

$$\begin{array}{ccc} RO: & Sb_2O_5: & H_2O \\ 3.14: & 10.00: & 5.92 \end{array}$$

If that water which escapes over sulphuric acid be considered true hygroscopic water, the ratio becomes 3.14 : 10.00 : 3.98. The first of these ratios corresponds to the formula 3 PbO, 2 Sb_2O_5, 6 H_2O, while the second is represented by 3 PbO, 2 Sb_2O_5, 4 H_2O.

KAOLINITE.

In the American Journal of Science, Vol. XXVII, 1884, p. 472, Mr. R. C. Hills gave a short description of the material whose chemical composition is discussed below. The mineral appears as a white or straw-colored powder, composed of minute scales, and occurs in certain vuggs or cavities in a quartz vein material, inclosed in a large mass of eruptive rock, of which it is an alteration product. Barite, galena, and occasionally other ore minerals are associated with the kaolinite. The National Belle mine, on Red Mountain, near Silverton, San Juan County, Colorado, is the original and principal locality for this mineral.

Under the microscope the powder resolves into a multitude of most perfect transparent crystals of hexagonal form, but evidently of the rhombic system, as shown by the optical action. They present a predominant basal plane, but also very distinctly a rhombic pyramid and a brachydome of very similar development, thus maintaining the resemblance to a hexagonal form. Figures illustrating these crystals accompanied Mr. Hill's description.

CHEMICAL COMPOSITION.—The material examined contained a number of black grains as an impurity, and was of a very faint straw-yellow color, from a thin coating of limonite. The latter was mostly removed by hydrochloric acid and the former by stirring up with water in a beaker, allowing the glass to stand for a moment and then pouring off what had not yet settled. The residue was again treated in a similar manner. From the decanted portion a very pure product was obtained, of brilliant whiteness.

The fine flakes, when suspended in quantity in water, impart to the latter a most beautiful satiny appearance.

At 18½° C. the specific gravity of the purified substance is 2.611. Before the blow-pipe intumescence takes place, but no fusion whatever. Strong boiling hydrochloric and sulphuric acids exercise little solvent action. The following are the results of analysis:

	LI.
SiO_2	46.85
Al_2O_3	39.59
Fe_2O_3	0.11
H_2O	13.93
F	*0.15
	100.18
Less O for F	.06
	100.07

*As mean of 0.17, 0 14, and 0.14.

The Fe_2O_3 comes undoubtedly from limonite which had not been entirely removed by hydrochloric acid.

None of the water escapes at a temperature of 330° C.; it is therefore probably all basic water. The text-books mention half the water of kaolinite as probably basic. If this is true, a marked distinction, aside from that occasioned by the presence of fluorine, exists between this mineral and kaolinite. Frenzel has described a variety of kaolin (myelin),[60] which loses none of its water until a very high temperature is reached.

This point should be carefully observed in future examinations of similar minerals, for upon the confirmation of such a difference as that mentioned, coupled, perhaps, with the presence of fluorine, there would be necessitated the separation of such minerals as the present one and myelin from kaolinite.

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[60] Naumann-Zirkel, Mineralogie, 11th ed., p. 676.

A CHROMIFEROUS PSEUDOMORPH.

From the Rochelle mine, on Running Water River, Wyoming Territory, there was obtained a single fragment of a dark green mineral, apparently a pseudomorph. Although crystal planes were visible, as well as more than one direction of cleavage, the identity of the original mineral could not be ascertained, partly owing to the cutting of artificial faces. In one direction, parallel to one of pronounced cleavage, a distinct lamination was observable. Edges and thin flakes were translucent. The lustre was greasy, and the color of the powder apple-green. Specific gravity at 12½° C., 2.831. Hardness about 3. Analysis gave:

	LII.	
SiO_2	45.54	45.24
Al_2O_3	37.15	38.07
Cr_2O_3	0.79	
MgO	0.38	0.34
K_2O	10.70	
Na_2O	0.90	
H_2O	4.80	
	100.26	

It is evident from the analysis that the product of alteration is allied to muscovite. With substitution of Fe_2O_3 for Cr_2O_3 the composition agrees almost exactly with that of the pseudomorph liebenerite.

NATIVE LEAD.

W. P. Blake describes in the American Journal of Science, Vol. XXV, p. 161, native lead occurring on galena, from the Jay Gould mine, Wood River district, Idaho Territory. A specimen of this occurrence in the collection of the Survey shows metallic lead, without any galena, running through a mass of quartz rock (the latter stained reddish, perhaps from minium). The quartz is somewhat cracked, and the several pieces are held in place by filaments of lead. A white coating of lead carbonate appears in a few small cavities. The lead is argentiferous.

VII.—NEW MINERAL SPECIES FROM COLORADO.

By W. F. HILLEBRAND.

ZUNYITE.

The Zuñi mine on Anvil Mountain, near Silverton, San Juan County, Colorado, has furnished to science two new minerals, one of them being of a remarkably interesting nature.

A portion of the ore from this mine, as represented by two specimens, for the use of which I am indebted to Mr. Franklin Guiterman, consists, when unaltered, of an uncrystallized sulphide of lead and arsenic, upon broken surfaces of which appear numberless projecting glassy faces of tetrahedra of the regular system. On destroying the sulphide by nitric or nitro-hydrochloric acid, washing thoroughly by decantation, and finally employing a solution of high specific gravity to effect separation from a very small amount of barite and whatever other lighter or heavier impurities may be present, a product is obtained consisting of fine crystals on which the predominant form is $\frac{O}{2}$, generally modified by $-\frac{O}{2}$, and frequently also by $\infty O \infty$ and $\frac{mOm}{2}$ (Whitman Cross). While goniometric measurements of the tetrahedral angles by Mr. Cross varied frequently within a degree from the normal, this must have been owing to surface irregularities, for generally the crystals are entirely without action on polarized light, and can therefore belong to none but the regular system, although a few show very faint polarization due to interior tension (Cross).

Their size varies from that of extreme minuteness to a diameter, in rare instances, of 5 millimeters. The smallest of the crystals are generally quite clear and transparent, but the vast majority carry more or less uncrystallized, unmagnetic, black inclusions, the nature of which the microscope does not reveal. Repeated preliminary tests showed that these were in no respect similar to the sulphide in which the crystals had been imbedded, being practically insoluble in the strongest acids, with the exception of hydrofluoric acid. The tetrahedra themselves, even in fine powder, are also unaffected by any acids other than hydrofluoric, and even with this acid the action is very slow. Fusion with potassium hydrosulphate effects decomposition in time, and with alkaline carbonates quite readily.

The lustre is glassy, cleavage octahedral, hardness about 7, and the specific gravity in the case of two different lots, carrying in so far as could be judged the same amount of inclusions, was 2.906 and 2.894, at 18½° C. and 20° C., respectively. By diluting a portion of the Thoulet solution until a few minute crystals free from black specks remained suspended in the liquid, and then taking the density of the latter by a Mohr balance, the specific gravity of the pure mineral was found to be 2.875 at 15° C.

The influence of the inclusions upon the specific gravity was not sufficient to allow of effecting anything like a complete separation, by the employment of a solution of high density, of pure matter from that carrying inclusions, even when finely powdered. For although the portions first falling consisted of the largest and blackest crystals or fragments, and each succeeding precipitate was of a slightly lighter shade, the last was still noticeably dark and by no means pure. The difficulty of separation in this manner was further enhanced by the fact that much of the material from which the portions taken for final analysis were obtained was more or less altered and consequently of lower specific gravity, the result being that the pure crystals and slightly altered ones containing many inclusions fell together. After very great labor, however, enough material for final tests was obtained by hand-picking under the loupe. This showed no signs of alteration and but here and there a minute black speck.

Qualitative analysis of less pure material showed the presence of silica, titanic oxide, alumina, ferric oxide, soda, potassa, lithia, fluorine, chlorine, phosphorus pentoxide, and water. When heated in a tube acid water which attacked glass was given off. Whole crystals when heated sometimes decrepitated, and always became opaque and porcelain-like, but showed no sign of fusion in the hottest blow-pipe flame.

On account of the hardness, which rendered grinding in an agate mortar unadvisable, the sample was crushed in a steel mortar, the metal from the latter extracted by hydrochloric acid, and, after washing thoroughly by filtration, the finest portions were separated from the coarse by levigating with water. The most impalpable powder was reserved for alkali tests.

In these, decomposition was effected by igniting with three parts of bismuth oxide for half an hour at a dull red heat. Treatment with hydrofluoric acid would have required several days for the decomposition alone, and it is improbable that the Lawrence Smith method would have succeeded well. Lithia could not be quantitatively estimated, although the spectroscopic evidence of its presence was strong.

Silica, alumina, ferric oxide, titanic oxide, and fluorine were generally estimated in the same portion, and, in one instance, also chlorine and phosphorus pentoxide. Fusion was made with potassium carbonate. After separation of silica, alumina, etc., in the usual manner, the phosphoric acid remaining in solution was removed by silver nitrate. The fluorine was not calculated from the weight of calcium fluoride obtained, but from the difference between this weight and that after conversion into sulphate. In one instance (analysis LV, below) a considerable amount of pure silica was added before fusion with alkaline carbonate, and here somewhat more fluorine was found than when no silica was added. Silica was always examined for phosphoric as well as for titanic acid when the latter was known to be present.

The solution containing ferric (titanic) and phosphoric oxides and alumina was divided into two parts, in the one of which the phosphorus was determined, in the other the weight of the combined oxides. The latter were brought into solution by fusion with potassium hydrosulphate; the titanic oxide if present was then thrown down by boiling in presence of sulphurous acid, and the iron was precipitated as sulphide from a tartaric acid solution and subsequently weighed as oxide. The alumina was found by difference.

Beryllia was carefully tested for by digesting the alumina and ferric oxide (introduced as chlorides) for several days with ammonium carbonate in excess. The very slight amount of matter found then in solution proved to be alumina.

Chlorine was estimated in a separate portion by precipitating as silver chloride in a platinum dish, after leaching the alkaline carbonate fusion and acidifying the filtrate with nitric acid. As a precautionary measure the chloride was then dissolved on the filter with ammonia and reprecipitated by nitric acid, after which it was collected and weighed in a Gooch crucible. In one instance the silver chloride thrown down before precipitating the fluorine as calcium fluoride was weighed and found to tally very closely with the results obtained on separate portions.

Water was estimated by heating the mineral with dry sodium carbonate in a glass tube and collecting in a weighed calcium chloride tube.

The results upon the purest material were as follows:

LIII.—0.9055 gram gave 0.2200 SiO_2, 0.0018 Fe_2O_3, 0.5230 Al_2O_3, and 0.0466 F.
LIV.—1.1568 gram gave 0.2817 SiO_2, 0.0022 Fe_2O_3, 0.6710 Al_2O_3 and 0.0613 F.
LV.—0.8136 gram gave 0.4882 Al_2O_3, 0.0018 Fe_2O_3, 0.0054 P_2O_5, 0.0244 Cl and 0.0473 F.
LVI.—0.6512 gram gave 0.0058 $Mg_2P_2O_7$, hence 0.0037 P_2O_5.
LVII.—1.0039 gram gave 0.0060 KCl, NaCl and trace LiCl, 0.0052 K_2PtCl_6, whence 0.0016 KCl and 0.0044 NaCl, LiCl, or 0.0010 K_2O and 0.0023 Na_2O, Li_2O.
LVIII.—1.0042 gram gave 0.0064 KCl, NaCl, LiCl, 0.0052 K_2PtCl_6, whence 0.0016 KCl and 0.0048 NaCl, LiCl, or 0.0010 K_2O and 0.0025 Na_2O, Li_2O.
LIX.—0.7022 gram gave 0.0824 AgCl, whence 0.0204 Cl.
LX.—0.7505 gram gave 0.0891 AgCl, whence 0.0220 Cl.
LXI.—0.5073 gram gave 0.0552 H_2O.
LXII.—0.4021 gram gave 0.0439 H_2O.
LXIII.—0.3502 gram gave 0.0381 H_2O.

	LIII.	LIV.	LV.	LVI.	LVII.	LVIII	LIX.	LX.	LXI.	LXII.	LXIII.	Mean.
SiO_2	24.30	24.36										24.33
Fe_2O_3	0.20	0.20	0.21									0.20
Al_2O_3	57.76	58.00	57.87									57.88
K_2O					0.10	0.10						0.10
Na_2O					0.23	0.25						0.24
Li_2O					trace.	trace.						trace
H_2O									10.88	10.92	10.88	10.89
P_2O_5			0.64	0.57								0.60
F.	5.15	5.30	5.61									*5.61
Cl			2.89				2.90	2.93				2.91
												102.76
Less O for F and Cl												3.02
												99.74

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* The highest figure for fluorine is here taken as probably nearer correct than the others, because of a possible analytical error in the latter having in this case been lessened by the addition of before making the alkaline fusion.

In deducing a formula from these data the Fe_2O_3 and P_2O_5 may for reasons subsequently mentioned be neglected. Since none of the water escapes at 270°C, it may be assumed that it exists as water of constitution, or basic water, and it is perhaps to be reckoned with the small quantities of alkalies. The atomic ratio is then found to be:

$$(H,K,Na) : Si : (Al_2) : (O,F_2,Cl_2)$$
$$1.2208 : 0.4055 : 0.5674 : 3.1232$$

or

$$18.06 : 6.00 : 8.39 : 46.21$$

which is not far from

$$18.00 : 6.00 : 8.00 : 45.00$$

giving the formula $R_{18}Si_6(Al_2)_8(O,F_2Cl_2)_{45}$ or 9 R_2O, 6 SiO_2, 8 Al_2O_3, with part of the oxygen replaced by fluorine and chlorine.

The Fe_2O_3 of the above analyses came undoubtedly from a thin film of ferric oxide on the tetrahedral crystals which had not been entirely removed by the various treatments with acids to which they had been subjected.

The P_2O_5 cannot well be a constituent of the tetrahedra and is probably derived from a small proportion of an admixed aluminium phosphate. The excess of alumina constantly found over that required for the above formula renders this the more likely. Evidence of the presence of an admixed phosphate was also obtained by direct experiment. In material not specially purified there were observed a few irregular and generally dull grains which at first were supposed to be fragments of tetrahedra, perhaps slightly altered. Half a dozen of these, weighing in all less than 1 milligram, were picked out, crushed, fused with sodium carbonate, the fusion dissolved in nitric acid, and a few drops of molybdate solution added. A distinct yellow precipitate formed in a short time. Yet while the presence of an aluminium phosphate would, by lowering the aluminium of the above analyses, make the ratio $Si:Al_2$ nearer 6:8 than it has been shown to be, I am not at all certain that the discrepancy is hereby entirely to be explained. For the given amount of SiO_2 only 55.19 per cent. of Al_2O_3 is required, leaving 2.69 per cent. for combination with only 0.60 per cent. of P_2O_5. Moreover, the above given ratio between SiO_2 and Al_2O_3 has been found by repeated careful analyses not included in the above, made on entirely different samples, to be practically constant. It is therefore possible that the true formula is more complex than that given above, or that some source of contamination exists which has as yet escaped detection.[61]

---

[61] After the above was ready for the press Mr. Cross communicated to me the following facts as the results of further microscopical examination:

"The zunyite has a polarizing inclusion, quite plentiful in a *few* crystals, but lacking entirely in most of them. When mounted in balsam the dark impurities stand out very plainly, causing the crystals to seem much more impure than they really are. The polarizing substance cannot be identified, but it is too brilliant for apatite. It has no good crystal form." This polarization, he further says, is distinct from that mentioned on p. 100, as occasionally shown by the zunyite itself. Hereby the opinion expressed above, that some foreign admixture was present, is confirmed.

As a name for the mineral, *Zunyite* is proposed, after the mine from which it was obtained.

The black inclusions in the zunyite were shown to contain titanic oxide by the following partial analyses of dark crystals:

SiO_2	23.93	23.86
TiO_2	0.75	0.84
Al_2O_3	*58.30	*58.45

*Not freed from Fe_2O_3 and P_2O_5.

In order to ascertain whether they consisted only of titanic oxide or of some titanate, an attempt was made to separate from the zunyite a quantity sufficient for analysis. It was soon found that this could be but very imperfectly accomplished and only by reducing large quantities of zunyite crystals to fine powder and then effecting the separation by means of the Thoulet solution. In this manner a mixture of barite, black particles, and attached zunyite was obtained, weighing, after thorough washing, but 0.5528 gram, which furnished the following results on analysis:

	LXIV.
$BaSO_4$	83.90
SiO_2	1.50
TiO_2	8.60
Al_2O_3	3.33
Fe_2O_3	0.20
P_2O_5	Trace.
H_2O, F, Cl, and loss	2.47
	100.00

Since the silica and alumina bear to each other nearly the same ratio as in zunyite, and since both fluorine and water were found to be present in small quantity, it is probable that all these were derived from attached zunyite, the perfect separation of which from the inclusions is practically impossible even with the comparatively large amounts operated upon. There remains then only titanic and a little ferric oxide, showing that the inclusions consist, in all probability, of titanic oxide alone.

By far the greater part of the zunyite-bearing ore seems to be in an advanced stage of decomposition. Through the kindness of Mr. J. A. Porter, of Durango, Colorado, the Colorado Scientific Society is the possessor of about fifty pounds of this altered ore completely filled with zunyite. The original double sulphide has almost disappeared, being changed into lead sulphate and other less well-defined compounds. While the zunyite is here in great measure still perfectly fresh, a considerable portion has been more or less altered, incipient change being indicated by a faint cloudiness through the crystals which, beginning apparently at the centre, spreads outward and increases in degree until, as a final product, there ensues a dull white opaque substance retaining in a measure the outlines of the original crystal and showing here and there a black grain of titanic oxide.

It was from this partially-altered ore that the material for the complete analysis above given and for the investigation of the inclusions was obtained, as the specimens of unaltered sulphide were two small to afford sufficient material by hand-picking.

A knowledge of the composition of the result of alteration of zunyite seemed desirable; hence the lightest of all portions separated by the Thoulet solution, of specific gravity 2.45, was partially analyzed. The result was unsatisfactory, indicating a mixture of probably several substances, of which a little undecomposed zunyite is known to be one, but the general character of the chemical change is in a measure shown.

	LXV.
SiO_2	56.47
Al_2O_3	22.08
Fe_2O_3	0.27
CaO(SrO?)	1.70
ZnO	0.20
K_2O	0.58
$Na_2O(Li_2O)$	1.29
P_2O_5	2.21
As_2O_5	0.40
SO_3	4.52
F	0.91
Cl	0.15
H_2O and loss	9.82
	100.00

Some of the constituents, as the As_2O_5 and ZnO, have evidently been derived from the sulphide ore in which the mineral was imbedded.

GUITERMANITE.

The metallic sulphide forming the matrix of the zunyite, of which in a fresh state, as before observed, but two specimens were at disposal, is of a bluish-gray color, possesses light metallic lustre, and a hardness of about 3 on places free from included zunyite. A small amount of pyrite is visible in spots.

Heated in the closed tube it fuses readily and there appears a slight sublimate of sulphur followed by a heavy one of arsenic sulphide; while on charcoal the usual reactions for sulphur, arsenic, and lead may be observed.

The following analyses were made:

	LXVI.			LXVII.		
	a.	*b.*	Mean.	*a.*	*b.*	Mean.
Zunyite	1.77	....	1.77	3.81	3.82	3.82
As	13.50	13.30	13.40	13.00	....	13.00
Pb	63.40	63.80	63.60	61.65	61.62	61.63
Cu	0.17	0.18	0.17	0.17	0.17	0.17
Ag	0.02	....	0.02	0.02	....	0.02
Fe	0.42	0.43	0.43	0.87	0.89	0.88
S	19.65	19.70	19.67	19.67	19.45	19.56
O	....	....	....	0.55	....	0.55
Total	98.93	....	99.06	99.74	....	99.63

Analyses LXVI *a* and *b* were first made, on material which had a specific gravity of 5.828 at 17½° C. Corrected for admixed zunyite of specific gravity 2.9, this becomes 5.94. As the total could hardly be brought above 99 per cent., in spite of great care in analyzing, the cause of this was sought for and found as will be subsequently explained.

In the experiments (not of a quantitative nature) having this end in view the sample was exhausted, therefore fresh material was used for two subsequent analyses, LXVII *a* and *b*.

In both these and the previous ones the sulphur was found in excess of that required for the metals, on the assumption that all the arsenic was present as trisulphide and the iron as disulphide. This was due to the presence of free sulphur, which was estimated quantitatively by extracting with carbon disulphide and carefully evaporating the filtrate to dryness in a weighed crucible. After three extractions no more sulphur was dissolved. The amount thus obtained represented 0.59 per cent. of the material used for analyses, LXVII, *a* and *b*.

While accounting completely and satisfactorily for the excess of sulphur, this did not explain the low summation shown in the first analyses. It was found, however, that notwithstanding the apparent purity of the mineral, lead sulphate was present in some quantity.

The sulphur trioxide of this was estimated by extracting the sulphate from the mineral by digestion with warm dilute hydrochloric acid in an atmosphere of carbonic acid, three or four digestions being sufficient for complete extraction, and, after partial neutralization of the filtrate, precipitating as barium sulphate. The result was 0.69 per cent. SO_3. The lead oxide of the sulphate could not be estimated in this extract, because even the dilute acid slightly decomposed the sulphide, taking lead but no arsenic into solution. Under the conditions of the experiment practically no hydrogen-sulphide could be oxidized in the short time required for making the extraction.

As a check, the lead oxide of the sulphate was estimated quantitatively by extracting the sulphate with neutral ammonium acetate in a closed flask, three or four digestions with fresh solution being sufficient, throwing down the lead as sulphide, and converting into sulphate before weighing. The percentage of lead oxide thus found was 2.70, instead 2.61 required by the 0.69 of SO_3 found. 2.61 of $PbSO_4$ contains 1.78 of lead, 0.28 of sulphur, and 0.55 of oxygen. Thus the sum total was brought much nearer to 100.

Excluding now the lead sulphate, free sulphur, and pyrite, the following atomic values are obtained:

Pb..........	59.85÷207. =0.2891	0.2904	3.35	10.05
Cu_2.........	0.17÷126.8=0.0013			
As_2..........	13.00÷150. =0.0866		1.00	3.00
S	17.68÷ 32. =0.5525		6.38	19.14

These lead to the formula 10 PbS, 3 As_2S_3. A simpler formula, and one not far removed from the above, is 3PbS, As_2S_3. If a small quantity of galena was present, of which, however, there was no evidence, other than that afforded by the decomposition of some lead sulphide by dilute hydrochloric acid without simultaneous solution of arsenic, the latter formula is probably the correct one. But this evidence is of little value, for any arsenic dissolved from the double sulphide would probably be immediately thrown down again by the hydrogen sulphide evolved. Whichever formula may be the true one, the mineral appears to be new to science, and a name, *Guitermanite*, is proposed, in honor of Mr. Franklin Guiterman, who first called attention to this and the associated zunyite.

In conclusion, a few words will be in place respecting the occurrence of these two new minerals. According to Mr. Guiterman there appears to be no decided indication of a fissure vein in the Zuñi mine, but the minerals occur in what seem to be pipe veins enlarged in places, the surrounding rock being probably andesite. In this and other mines of the region kaolinization of the country rock is a marked feature.

A PROBABLY NEW MINERAL.

A portion of the ore from the Missouri mine, Hall's Valley, Park County, Colorado, is composed largely of a sulpho-bismuthide of copper and silver. It occurs in a quartz gangue associated with chalcopyrite and wolframite, and although the latter is only visible on close examination, it comprises from 1 to 2 per cent. of the whole, as found by special tests. A considerable quantity was extracted by chemical and mechanical means, free from all foreign matter except a little attached quartz, and was proven to be wolframite by qualitative chemical tests and by a determination of the specific gravity.

The mass of the sulpho-bismuthide appears throughout the quartz as a dark, bluish-gray substance without distinct forms of crystallization. In numerous cavities appear small slender crystals, generally bronzed by oxidation and so deeply striated as sometimes to present the appearance under the loupe of bunches of needles. Occasionally they seem to be joined together laterally forming thin corrugated plates. Owing to this deep striation no crystal faces can be detected either on the sides or the free terminations. The habit is strikingly like that of bismuthinite, for which the crystals were, indeed, at first taken.

After several days labor enough material was removed from the cavities for the determination of the metals. It could not, however, be freed altogether from quartz and chalcopyrite. The specific gravity at 17° C. was 5.75. Making correction for 4.43 per cent. of quartz and 6.98 per cent. of chalcopyrite of assumed specific gravities 2.65 and 4.2, this becomes 6.31. The analysis appears under LXVIII below.

The more compact material, excluding as far as possible the needles, gave, after deducting 59.75 per cent. of gangue, the results under LXIX.

LXX is the analysis of a mineral presented by Mr. William McCree as coming probably from the Missouri mine. In appearance it differs in no respect from the compact material already described, except that no chalcopyrite is distinctly visible in the small specimens at my disposal, and the quartz grains are less firmly cemented together. It contains, however, some lead, which is entirely wanting in the other specimens analyzed, although the general formula is the same; hence I am led to believe that it came from some other portion of the workings or from an adjacent mine where ore like that from the Missouri mine is reported to occur. The specific gravity was 3,869 at 15° C., which becomes 6.680 on making correction for 47.57 per cent. of gangue of ascertained specific gravity 2.643.

The most marked blow-pipe reactions for LXVIII, LXIX, and LXX, were entirely similar, a sublimate of sulphur appearing in the closed tube, sulphur dioxide escaping in the open tube, and the fused fragment or powder on charcoal affording the bismuth reactions with great intensity. All were soluble in nitric and hydrochloric acids, in the latter with precipitation of silver chloride.

	LXVIII.	LXIX.	LXX.
Bi	60.74	60.86	62.45
Ag	0.89	4.09	9.89
Cu	15.96	12.65	6.68
Pb	....	....	2.74
Fe	2.18	0.59	0.10
Zn	0.10	0.07	0.07
S	*19.94	*18.83	17.90
	99.76	99.59	99.83

*Calculated.

After subtracting from LXVIII 6.97 per cent.; from LXIX, 1.91 per cent., and from LXX, 0.33 per cent. of chalcopyrite, with the proportions of sphalerite represented by the zinc, the atomic ratios become:

	R	:	Bi_2	:	S.
LXVIII.	3.00	:	3.95	:	14.75.
LXIX.	3.00	:	4.03	:	14.98.
LXX.	3.00	:	4.10	:	15.15.

where R represents Pb and the double atoms Ag_2 and Cu_2. In each case the ratio is nearly 3 : 4 : 15, which leads to the general formula $3RS + 4Bi_2S_3$.

It seems probable that the needle-like crystals are a pure sulphobismuthide of copper, and that in the more compact portions silver replaces a part of the copper, and in some cases a further replacement of copper by lead takes place.

This ore from the Missouri mine is auriferous. The material used for analysis LXIX, gangue and sulphide together, assayed 1.85 ounces gold to the ton. According to Mr. Pearce, of the Boston and Colorado Smelting Works, it was frequently much richer, running as high as 40 ounces to the ton.

Before conferring a name upon this mineral, or even definitely claiming it as a new species, further investigation is advisable. A personal visit to the Missouri and other neighboring mines in October, 1884, in the hope of obtaining better material, was not rewarded with success.

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EXPLANATION OF PLATE.

Fig. 1 illustrates the twin structure and optical properties of stilbite, seen in clinopinacoidal section, as described by von Lasaulx. See text, p. 20.

Fig. 2 illustrates the twin structure and optical properties of stilbite from Table Mountain, in corresponding position to that of Fig. 1. See text, p. 21.

Fig. 3 illustrates the twin structure and optical properties of phillipsite, as described by Trippke. See text, p. 23.

Figs. 4, 5, and 6 show the optical anomalies observed in the apophyllite of Table Mountain, by C. Klein. See text, p. 30.

Figs. 7, 8, 9, and 10 illustrate the polysynthetic twin structure observed in the cryolite of Saint Peter's Dome. See text, pp. 43–47.

Fig. 11 represents the crystal form of prosopite from Saint Peter's Dome. See text, p. 63.

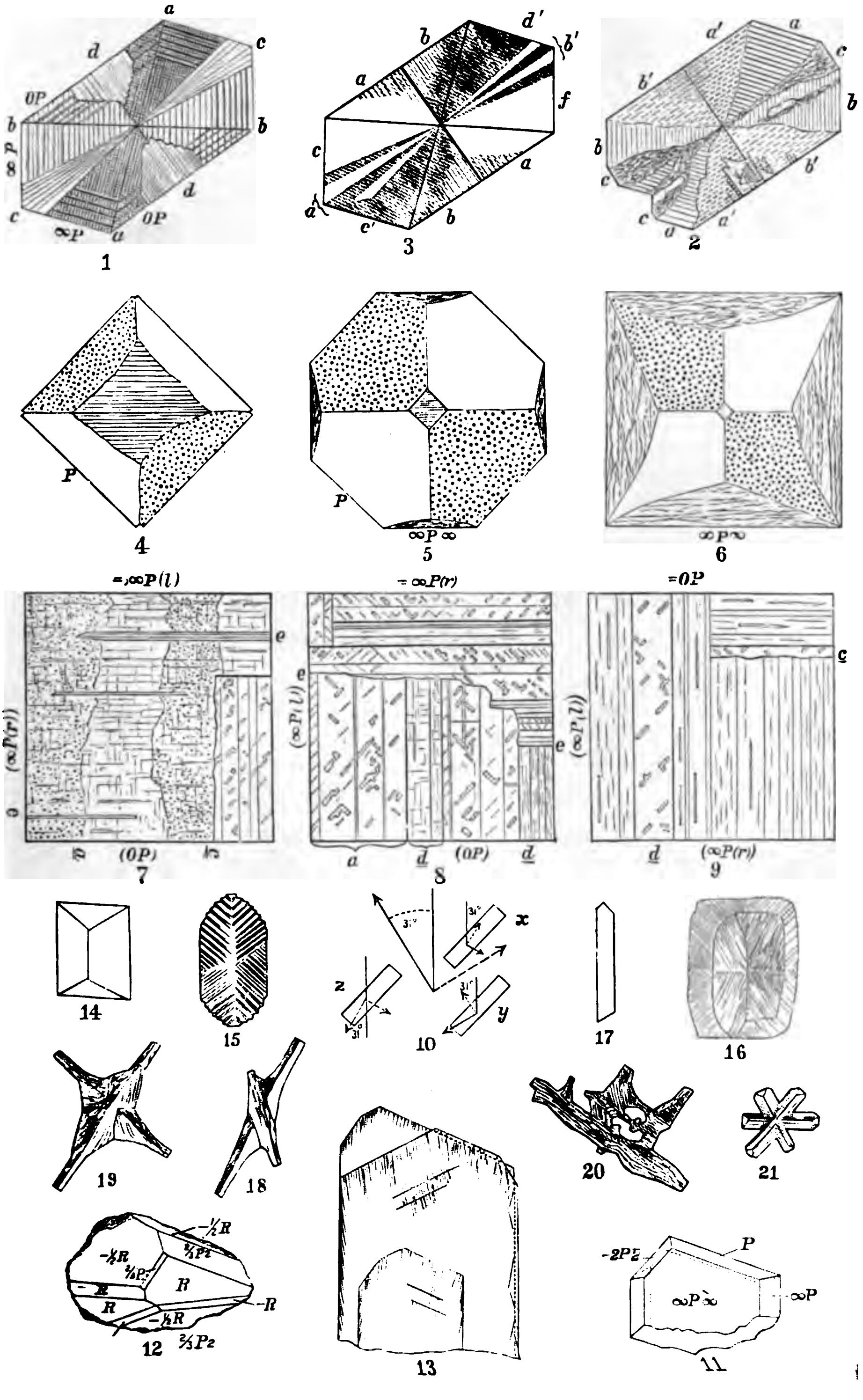
Fig. 12 represents a crystal of phenacite from Crystal Park, natural size. See text, p. 68.

Fig. 13 shows the position of the parting which produces the lustre of the sanidine in the nevadite of Chalk Mountain. See text, p. 76.

Fig. 14 the fundamental form of löllingite. See text, p. 90.

Figs. 15 and 16, forms of löllingite, observed in the material from Gunnison County, Colorado. See text, p. 90–91.

Figs. 17, 18, 19, 20, and 21 represent different forms of a rhombic arsenide of iron, cobalt, and nickel, observed in association with löllingite, Gunnison County, Colorado. See text, p. 91.



COLORADO MINERALS.

DEPARTMENT OF THE INTERIOR

BULLETIN

OF THE

UNITED STATES

GEOLOGICAL SURVEY

No. 21

THE LIGNITES OF THE GREAT SIOUX RESERVATION—A
REPORT ON THE REGION BETWEEN THE GRAND
AND MOREAU RIVERS DAKOTA

WASHINGTON
GOVERNMENT PRINTING OFFICE
1885

ADVERTISEMENT.

[Bulletin No. 21.]

The publications of the United States Geological Survey are issued in accordance with the statute, approved March 3, 1879, which declares that—

"The publications of the Geological Survey shall consist of the annual report of operations, geological and economic maps illustrating the resources and classification of the lands, and reports upon general and economic geology and paleontology. The annual report of operations of the Geological Survey shall accompany the annual report of the Secretary of the Interior. All special memoirs and reports of said Survey shall be issued in uniform quarto series if deemed necessary by the Director, but otherwise in ordinary octavos. Three thousand copies of each shall be published for scientific exchanges and for sale at the price of publication; and all literary and cartographic materials received in exchange shall be the property of the United States and form a part of the library of the organization: And the money resulting from the sale of such publications shall be covered into the Treasury of the United States."

On July 7, 1882, the following joint resolution, referring to all Government publications, was passed by Congress:

"That whenever any document or report shall be ordered printed by Congress, there shall be printed in addition to the number in each case stated, the 'usual number' (1,900) of copies for binding and distribution among those entitled to receive them."

Under these general laws it will be seen that none of the Survey publications are furnished to it for gratuitous distribution. The 3,000 copies of the Annual Report are distributed through the document rooms of Congress. The 1,900 copies of each of the publications are distributed to the officers of the legislative and executive departments and to stated depositories throughout the United States.

Except, therefore, in those cases where an extra number of any publication is supplied to this office by special resolution of Congress, as has been done in the case of the Second, Third, Fourth, and Fifth Annual Reports, or where a number has been ordered for its use by the Secretary of the Interior, as in the case of Mineral Resources and Dictionary of Altitudes, the Survey has no copies of any of its publications for gratuitous distribution.

ANNUAL REPORTS.

Of the Annual Reports there have been already published:

I. First Annual Report to the Hon. Carl Schurz, by Clarence King. 1880. 8°. 79 pp. 1 map.—A preliminary report describing plan of organization and publications.

II. Report of the Director of the United States Geological Survey for 1880–'81, by J. W. Powell. 1882. 8°. lv, 588 pp. 61 pl. 1 map.

III. Third Annual Report of the United States Geological Survey, 1881–'82, by J. W. Powell. 1883 8°. xviii, 564 pp. 67 pl. and maps.

IV. Fourth Annual Report of the United States Geological Survey, 1882–'83, by J. W. Powell. 1884. 8°. xii, 473 pp. 85 pl. and maps.

The Fifth Annual Report is in press.

MONOGRAPHS.

Of the Monographs, Nos. II, III, IV, V, VI, VII, and VIII are now published, viz:

II. Tertiary History of the Grand Cañon District, with atlas, by Clarence E. Dutton, Capt., U. S. A. 1882. 4°. xiv, 264 pp. 42 pl. and atlas of 24 sheets folio. Price $10.12.

III. Geology of the Comstock Lode and the Washoe District, with atlas, by George F. Becker. 1882. 4°. xv, 422 pp. 7 pl. and atlas of 21 sheets folio. Price $11.

IV. Comstock Mining and Miners, by Eliot Lord. 1883. 4°. xiv, 451 pp. 3 pl. Price $1.50.

V. Copper-bearing Rocks of Lake Superior, by Roland D. Irving. 1883. 4°. xvi, 464 pp. 15 l. 29 pl. Price $1.85.

VI. Contributions to the Knowledge of the Older Mesozoic Flora of Virginia, by Wm. M. Fontaine. 1883. 4°. xi, 144 pp. 54 l. 54 pl. Price $1.05.

VII. Silver-lead Deposits of Eureka, Nevada, by Joseph S. Curtis. 1884. 4°. xiii, 200 pp. 16 pl. Price $1.20.

VIII. Paleontology of the Eureka District, by Charles D. Walcott. 1884. 4°. xiii, 298 pp. 24 l. 24 pl. Price $1.10.

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The following are in press, viz:

IX. Brachiopoda and Lamellibranchiata of the Raritan Clays and Greensand Marls of New Jersey, by Robert P. Whitfield. 1885. 4°. ix, 338 pp. 35 pl.

X. Dinocerata. A Monograph of an Extinct Order of Gigantic Mammals, by Othniel Charles Marsh. 1886. 4°. —, — pp. 56 pl.

XI. Geological History of Lake Lahontan, a Quaternary Lake of Northwestern Nevada, by Israel Cook Russell. 1885. 4°. —, — pp. 46 pl.

The following are in preparation, viz:

I. The Precious Metals, by Clarence King.

Geology and Mining Industry of Leadville, with atlas, by S. F. Emmons.

Geology of the Eureka Mining District, Nevada, with atlas, by Arnold Hague.

Lake Bonneville, by G. K. Gilbert.

Sauropoda, by Prof. O. C. Marsh.

Stegosauria, by Prof. O. C. Marsh.

BULLETINS.

The Bulletins of the Survey will contain such papers relating to the general purpose of its work as do not properly come under the heads of ANNUAL REPORTS or MONOGRAPHS.

Each of these Bulletins will contain but one paper and will be complete in itself. They will, however, be numbered in a continuous series, and will in time be united into volumes of convenient size. To facilitate this each Bulletin will have two paginations, one proper to itself and another which belongs to it as part of the volume.

Of this series of Bulletins Nos. 1 to 21 are already published, viz:

1. On Hypersthene-Andesite and on Triclinic Pyroxene in Augitic Rocks, by Whitman Cross, with a Geological Sketch of Buffalo Peaks, Colorado, by S. F. Emmons. 1883. 8°. 42 pp. 2 pl. Price 10 cents.

2. Gold and Silver Conversion Tables, giving the coining value of Troy ounces of fine metal, etc., by Albert Williams, jr. 1883. 8°. ii, 8 pp. Price 5 cents.

3. On the Fossil Faunas of the Upper Devonian, along the meridian of 76° 30′, from Tompkins County, New York, to Bradford County, Pennsylvania, by Henry S. Williams. 1884. 8°. 36 pp. Price 5 cents

4. On Mesozoic Fossils, by Charles A. White. 1884. 8°. 36 pp. 9 pl. Price 5 cents.

5. A Dictionary of Altitudes in the United States, compiled by Henry Gannett. 1884. 8°. 325 pp. Price 20 cents.

6. Elevations in the Dominion of Canada, by J. W. Spencer. 1884. 8°. 43 pp. Price 5 cents.

7. Mapoteca Geologica Americana. A catalogue of geological maps of America (North and South), 1752–1881, by Jules Marcou and John Belknap Marcou. 1884. 8°. 184 pp. Price 10 cents.

8. On Secondary Enlargements of Mineral Fragments in Certain Rocks, by R. D. Irving and C. R. Vanhise. 1884. 8°. 56 pp. 6 pl. Price 10 cents.

9. A Report of work done in the Washington Laboratory during the fiscal year 1883–'84. F. W. Clarke, chief chemist; T. M. Chatard, assistant. 1884. 8°. 40 pp. Price 5 cents.

10. On the Cambrian Faunas of North America. Preliminary studies by Charles Doolittle Walcott. 1884. 8°. 74 pp. 10 pl. Price 5 cents.

11. On the Quaternary and Recent Mollusca of the Great Basin; with Descriptions of New Forms, by R. Ellsworth Call; introduced by a sketch of the Quaternary Lakes of the Great Basin, by G. K. Gilbert. 1884. 8°. 66 pp. 6 pl. Price 5 cents.

12. A Crystallographic Study of the Thinolite of Lake Lahontan, by Edward S. Dana. 1884. 8°, 34 pp. 3 pl. Price 5 cents.

13. Boundaries of the United States and of the several States and Territories, by Henry Gannett. 1885. 8°. 135 pp. Price 10 cents.

14. The Electrical and Magnetic Properties of the Iron-Carburets, by Carl Barus and Vincent Strouhal. 1885. 8°. 238 pp. Price 15 cents.

15. On the Mesozoic and Cenozoic Paleontology of California, by Dr. C. A. White. 1885. 8°. 33 pp. Price 5 cents.

16. On the higher Devonian Faunas of Ontario County, New York, by J. M. Clarke. 1885. 8°. 86 pp. 3 pl. Price 10 cents.

17. On the Development of Crystallization, etc., by Arnold Hague and J. P. Iddings. 1885. 8°. 44 pp. Price 5 cents.

18. On Marine Eocene, Fresh-water Miocene, and other Fossil Mollusca of Western North America, by Dr. C. A. White. 1885. 8°. 26 pp. 3 pl. Price 5 cents.

19. Notes on the Stratigraphy of California, by George F. Becker. 1885. 8°. 28 pp. Price 5 cents.

20. Contributions to the Mineralogy of the Rocky Mountains, by Whitman Cross and W. F. Hillebrand. 1885. 8°. 114 pp. 1 pl. Price 10 cents.

21. The Lignites of the Great Sioux Reservation, by Bailey Willis. 1885. 8°. 16 pp. 5 pl. Price 5 cents.

Numbers 1 to 6 of the Bulletins form Volume I, and numbers 7 to 14 Volume II. Volume III is not yet complete.

The following are in press, viz:

ADVERTISEMENT.

22. On New Cretaceous Fossils from California, by Charles A. White, M. D. 1885. 8°. — pp. 5 pl. Price — cents.

23. The Junction between the Eastern Sandstone and the Keweenaw series on Keweenaw Point, by R. D. Irving and T. C. Chamberlain. 1885. 8°. — pp. 17 pl. Price — cents.

24. List of Marine Mollusca, comprising the quaternary fossils and recent forms from American localities between Cape Hatteras and Cape Roque, including the Bermudas, by W. H. Dall. 1885. 8°. — pp. Price — cents.

STATISTICAL PAPERS.

A fourth series of publications having special reference to the mineral resources of the United States is contemplated.

Of that series the first has been published, viz:

Mineral Resources of the United States, by Albert Williams, jr. 1883. 8°. xvii, 813 pp. Price 50 cents.

The second volume of this series, Mineral Resources 1883 and 1884, is in preparation and will soon be put to press.

Correspondence relating to the publications of the Survey, and all remittances, which must be by POSTAL NOTE OR MONEY ORDER, should be addressed

TO THE DIRECTOR OF THE
UNITED STATES GEOLOGICAL SURVEY,
Washington, D. C.

WASHINGTON, D. C., *June* 25, 1885.

DEPARTMENT OF THE INTERIOR

BULLETIN

OF THE

UNITED STATES

GEOLOGICAL SURVEY

No. 21

WASHINGTON
GOVERNMENT PRINTING OFFICE
1885

UNITED STATES GEOLOGICAL SURVEY
J. W. POWELL DIRECTOR

THE LIGNITES

OF THE

GREAT SIOUX RESERVATION

A REPORT ON THE REGION BETWEEN THE GRAND AND MOREAU RIVERS DAKOTA

BY

BAILEY WILLIS

WASHINGTON
GOVERNMENT PRINTING OFFICE
1885

LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
Washington, April 13, 1885.

SIR: I have the honor to transmit herewith a report on the lignite beds of the Great Sioux Reservation, Dakota, the result of the survey ordered in your instructions to me under date of July 17, 1884.

Very respectfully,

BAILEY WILLIS,
Geologist.

Hon. J. W. POWELL,
Director United States Geological Survey.

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LIGNITES OF THE GREAT SIOUX RESERVATION.

By **Bailey Willis.**

INTRODUCTORY.

Under the instructions of the Director of the United States Geological Survey, dated July 17, 1884, a party was organized and started from Mandan, Dakota, on July 24, to determine whether coal-beds of economic value exist within the Great Sioux Reservation, particularly near the Moreau River, and, if so, to define the limits of the coal-field. The party proceeded, by way of Standing Rock Agency, to the mouth of the Moreau (Fig. 1), where it was detained five days by Cheyenne Indians. It then went westward over the high prairie within the bend to the north which the Moreau makes in approaching the Missouri, crossed to the north bank 21½ miles west of the latter river, and ascended to the divide between the Moreau and Grand rivers.

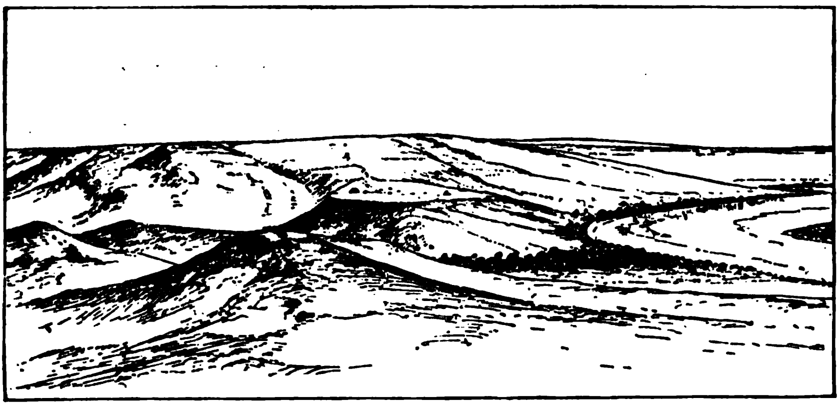

Fig. 1.—Mouth of the Moreau, looking north.

Upon this long, narrow plateau, 60 miles from the Missouri, the first beds of inferior lignite were found. With a greatest thickness of 2 feet 4 inches, these beds possess no commercial value; and, though the energies of the party were devoted to an examination of this formation for good fuel over an area of 2,000 square miles, the search was in vain.

It may be definitely said there is no workable coal of any kind within the area surveyed; the fuel supply will be limited to the scattered groves of cottonwood along the principal streams for a period dependent on the growth of transportation facilities; and the scarcity of fuel and water will prevent close settlement for a long time.

DESCRIPTIVE.

The general easterly course of the rivers flowing through the Sioux Reservation to the Missouri defines the gentle slope of the plateau lying east and northeast of the Black Hills; at its eastern rim, along the Missouri, its elevation is about 400 feet above the river, or 1,900 feet above the sea, and the ascent westward is barely perceptible.

Into this plateau the Cheyenne, Moreau, Grand, and Cannon-ball Rivers have cut tortuous, narrow valleys, 200 to 300 feet lower than the bluffs that bound them, and the small tributaries of these streams have slashed the bordering highland into an intricate radiating system of gulches and ridges. Between the waterways extend strips of rolling prairie, upon which stand isolated truncated or conical buttes 100 to 250 feet high, witnesses of the degradation suffered by the soft strata of the old plain.

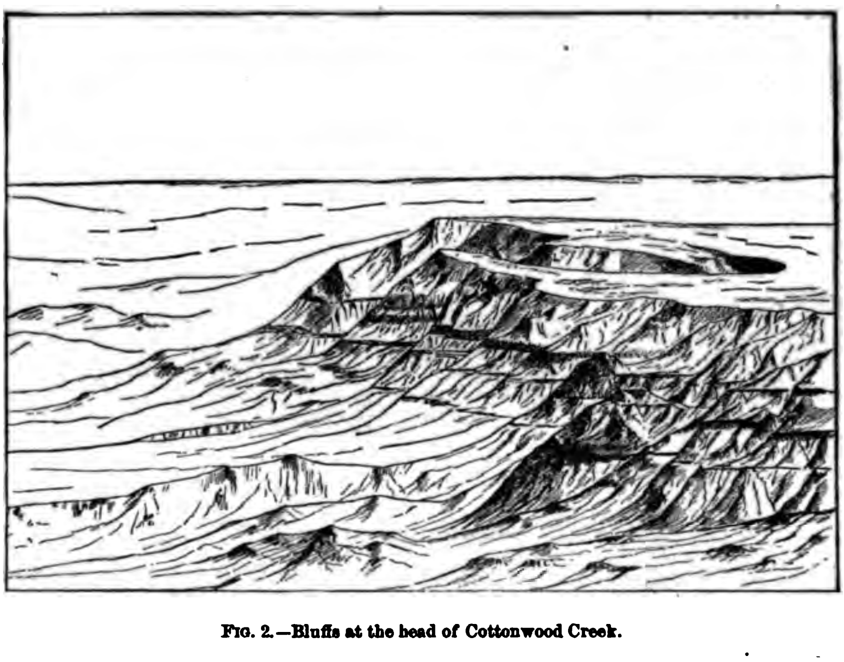
FIG. 2.—Bluffs at the head of Cottonwood Creek.

Water flows sluggishly the year round in the larger tributaries of the rivers, such as Flint, Cottonwood, Black Horse, and Thunder creeks, and may be found in water-holes in many of the gulches throughout the summer. Those streams that have cut down into the dark "gumbo" clay of the Missouri bluffs are alkaline, while those which flow over the sandy beds of the Laramie are often only slightly so, or quite pleasant to the taste.

Within the area of the accompanying map the valleys of Cottonwood creek and of the Moreau slope directly south of it, are localities of greatest erosion, which partake of the bad land character, and their surface is scored with naked gullies (Fig. 2). The remaining greater portion of the region is grass-covered, and the "lay of the land" is favorable to stock-raising.

An interesting feature of the surface geology is the occurrence of erratic blocks of quartzite and granite on many of the elevations of the prairie. Some pieces of the quartzite contain silicified wood, which probably identifies it with the Dakota quartzites of the Black Hills, but more frequently the fragments are pierced with casts of stems from which the core has been removed. The surfaces of the blocks are highly polished by drifting sand, as was first shown by Dr. C. A. White, and the silicified wood has apparently been excavated from these casts by the same means, aided by alkali.

GEOLOGY

From Mandan to the Moreau and thence west to Rabbit butte two deposits were recognized, which have been determined by Mr. J. B. Marcou to be of the Laramie and Fox Hills formations, both of which are placed in the Cretaceous group in the present classification of the Geological Survey. They are conformable throughout this region, and the boundary between them is often not easily defined.

The following table indicates the evidence of age:

Formation.	Fossils.	Lithology.
Laramie	*Ostrea glabra*, M. & H. *Melania insculpta*, M	Light-yellow, gray, and dark-brown sandstones and arenaceous shales, with thin beds of lignite and iron nodules.
Upper Fox Hills	*Tancredia Americana*, M. & H.	Brownish sandstone.
Fox Hills	*Cucullæa* (*Idonearca*) *Shumardi*, M. & H. *Scaphites Cheyennensis*, Owen (sp.) *Turris* (*Surcula*) ? *contortus*, M. & H.	Grayish-blue shale below brownish unfossiliferous sandstone.
Lower Fox Hills (= Fort Pierre of Hayden in part.)	*Volsella attenuata*, M. & H. *Scaphites Conradi*? var. *intermedius*, M. & H. *Scaphites Cheyennensis*, Owen (sp.) *Pteria* (*Oxytoma*) *Nebrascana*, E. & S. *Spironema tenuilineata*, M. & H. (sp.) *Cucullæa exigua*, M. & H.	Dark-gray to blue-black tenacious alkaline clays, locally hardened to compact clay rock.

Rising from the Missouri over the dark clays of the lower formation (which in lithologic character corresponds to the upper part of Hayden's Fort Pierre, but is paleontologically identifiable with the Fox Hills), the Laramie first appears as a hard, gray, fine-grained sandstone, capping the isolated buttes on the plateau, which near the Moreau begin about 35 miles west of the Missouri. The following sketch shows the effect of these caps on Flint Creek bluffs. (Fig. 3).

With the irregularity of character and thickness of the Laramie beds, this sandstone grades over large areas into arenaceous shale or becomes soft and incoherent, and there is then much difficulty in determining its correct position.

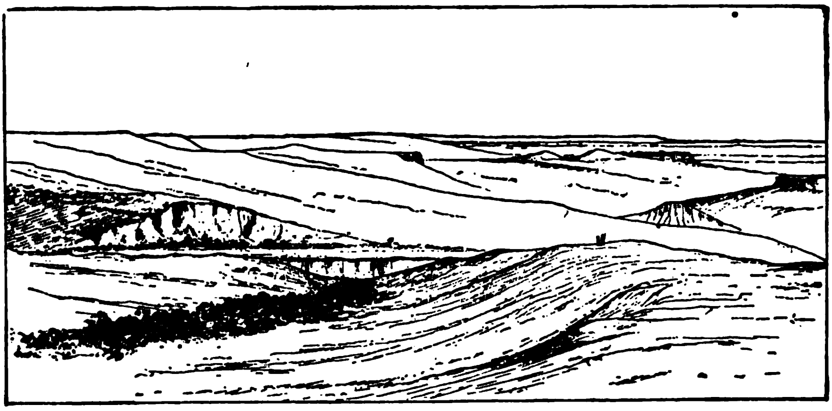

FIG. 3.—Sandstone bluffs on Flint Creek.

The Laramie fossils were taken from accumulations of broken shells just above the horizon of this sandstone on Cottonwood and Thunder creeks, where they formed beds 6 to 15 feet thick and of several hundred feet lateral extent, evidently the wash of eddies.

The upper Fox Hills *Tancredia* was found in a brownish sand immediately below the gray Laramie sandstone at the lower crossing of Flint creek (see Plate II, Fig. 5); the Fox Hills fossils are from a gray shale immediately underlying a similar brownish sand-bed on the Moreau one-half mile below the mouth of Thunder creek; while those assigned to the Fox Hills and Fort Pierre represent a horizon still lower in the blue clays in a locality on Grand River 15 miles east of Flint creek. Thus it appears that there is a gradual transition in this locality from the upper Fort Pierre clays through not more than 100 feet of Fox Hills beds to the lower sandstone of the Laramie.

The strata are practically horizontal over large areas, but sometimes show local dips of 1° to 3°. On the assumption that these local dips balance each other between the eastern limit of the Laramie on the Moreau and the top of Rabbit butte, the observed thickness of that formation is about 700 feet—probably less than half the original thickness over this area.

The two thickest sections observed are those illustrated in Figures 1 and 2 of Plate I, and Figures 5 and 6 of Plate III. The first is 348 feet, and the second 476 feet thick. If we could assume that the strata were absolutely horizontal from Black Horse butte to Rabbit Creek, these two might be combined to form a section of 746 feet ot the lower Laramie, which would include thirteen lignite beds; but aside from the improbability of absolute horizontality of the beds over a distance of thirty odd miles, the section would have no representative value, as the beds of sandstone, shale, lignite, and iron ore pass into each other by abrupt changes of composition. This is illustrated in Plates II and III, where the sections are placed as nearly as possible in their relative vertical positions.

COAL.

The reports of the existence of coal in the Sioux Reservation, which led to this exploration, originated in the presence of lignite in sufficient quantity to furnish good specimens, and in the representations of Indians that they had found pieces of eastern coal, shown by them, on the reservation; which was true in so far as they found them at the agency blacksmith shops. There is no other coal than lignite on the reservation, and that is of poor quality. This result agrees with all observations of the Laramie coal-beds, which occur as typical lignites over thousands of square miles in the west, and are only altered to more condensed fuels in regions of intense local metamorphism.

The best exposure of lignite found is represented in Fig. 4. It crops out in a little roll of the surface on one of the head branches of Flint creek. A careful section of a fresh cut gave: Roof (gray clay); earthy lignite, 3 inches; lignite, 2 feet 4 inches; earthy lignite, 6 inches; foot-wall (gray clay).

Three hundred feet to the right of the section a bed of nodules of iron carbonate replaced the lignite. Four hundred feet off on the other side it had deteriorated to a brown clay. The other carbonaceous beds, ranging from brown shale to fair lignite, are shown in their proper relations on Plates I, II, and III.

The manner in which these beds suddenly end is shown in one of the many cases observed in the lowest layer of Fig. 6, Plate III.

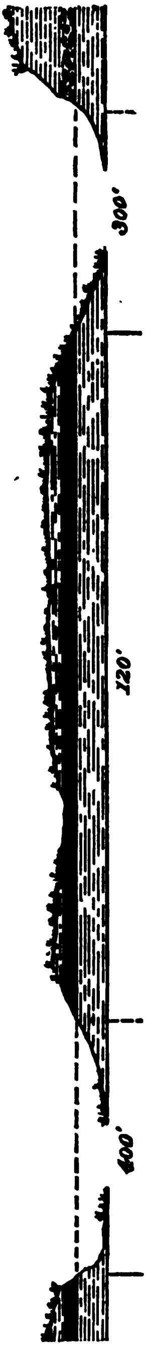

FIG. 4.—Section of lignite bed.

As indicated in Fig. 4, lignites sometimes occupy the same horizon with nodular iron ores. The two have not been observed intermingled, though they might occur thus, and would then form blackband ore.

The iron nodules are of gray carbonate of iron, oxidized on the outside to limonite, which often has a dark reddish tint indicating an approach to the composition of hematite. The shrinkage in volume of this oxidized layer cracks it into polygonal bits that adhere firmly to the unaltered core. In this respect these carbonates differ from those of the eastern coal measures, which alter into shells of limonite, readily separable from each other and from the core.

These ores are too far from fuel and limestone to have commercial value.

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Fig. 1.

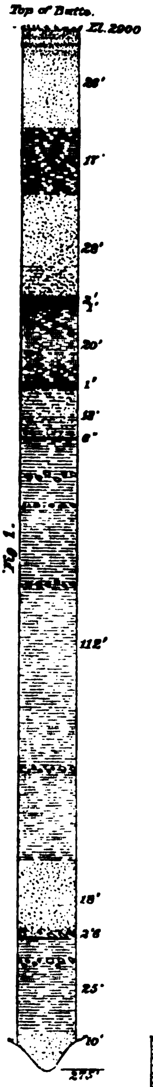


Fig. 2.

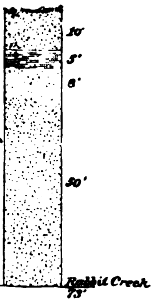


Fig. 3.

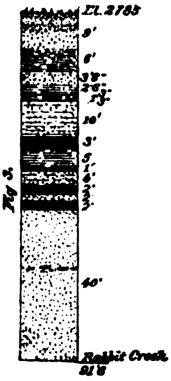


Fig. 4.

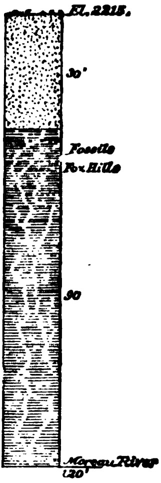
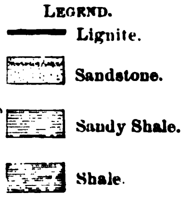
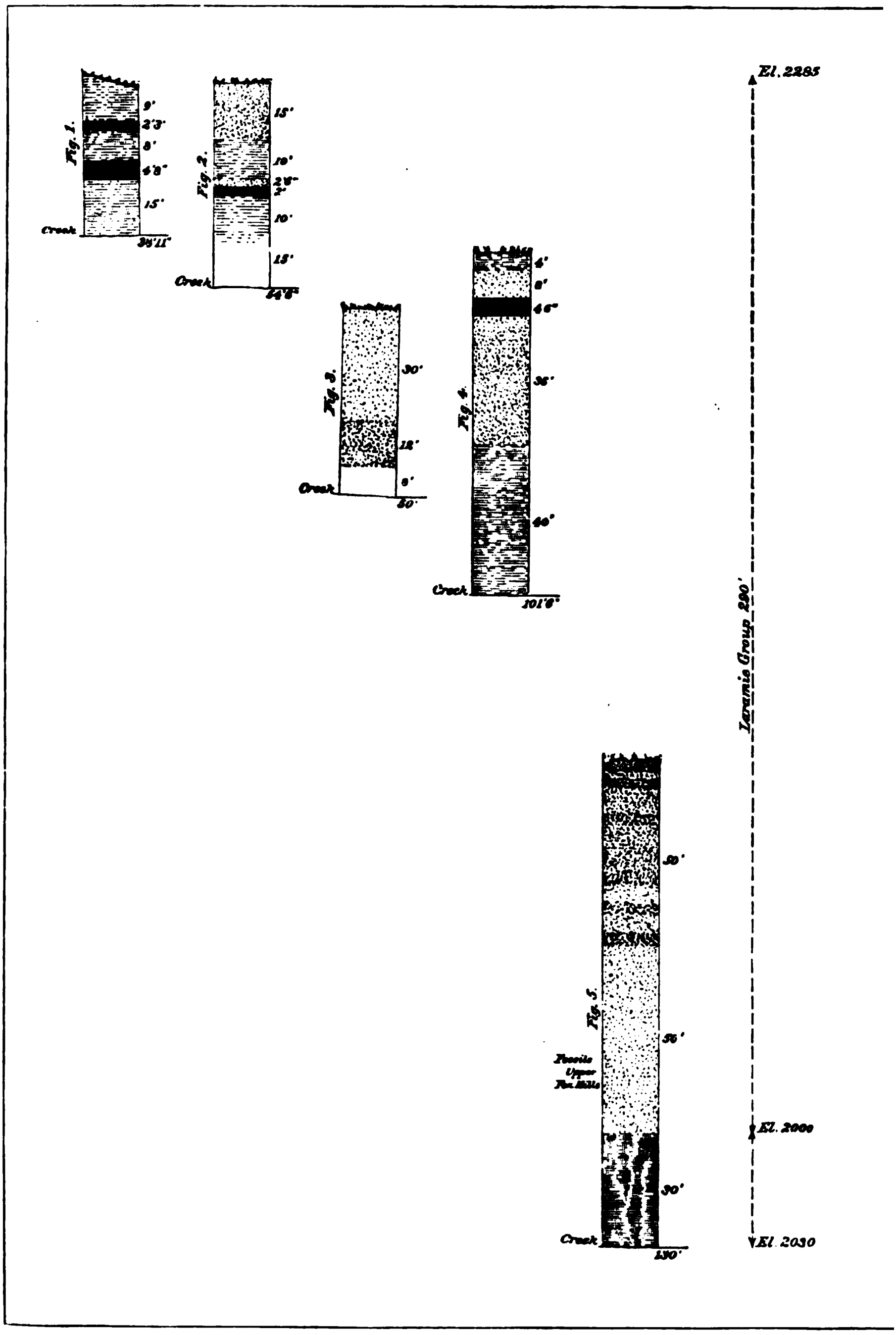


Fig. 5



SECTIONS OF THE LARAMIE—RABBIT CREEK AND MOREAU RIVER.



SECTIONS OF THE LARAMIE—FLINT CREEK.

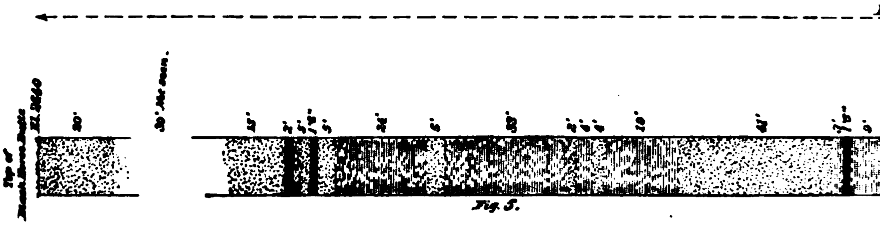


Fig. 5.

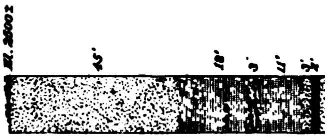


Fig. 3.

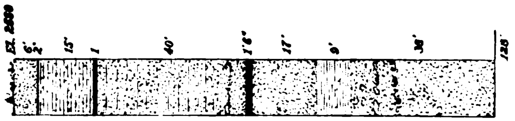


Fig. 2.

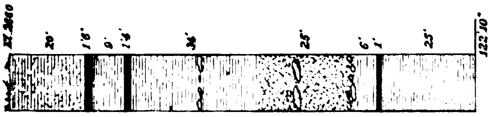


Fig. 1.

SECTIONS OF THE LARAMIE—BLAC

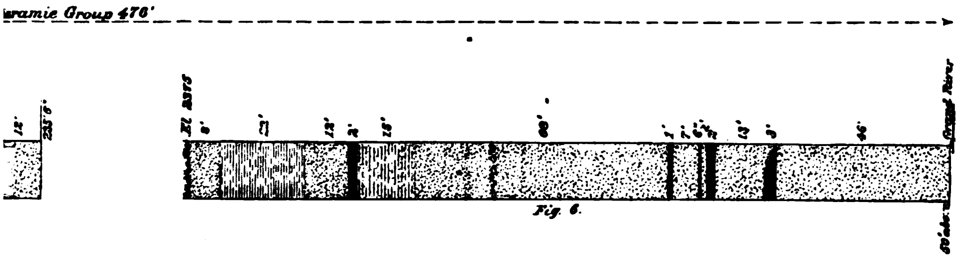


Fig. 6.

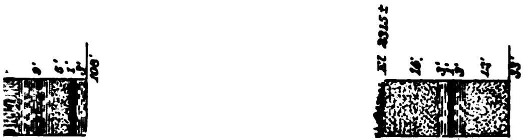
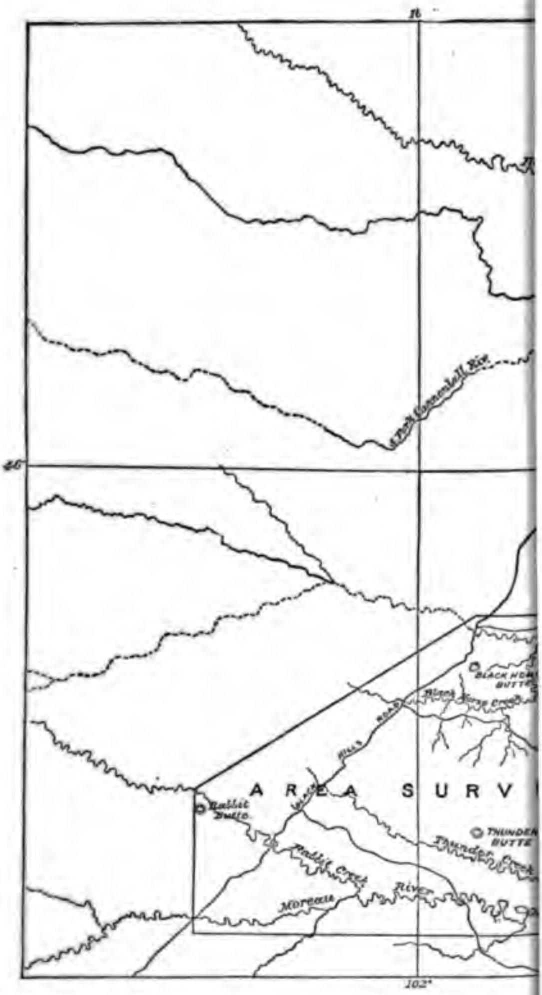


Fig. 4.

HORSE CREEK AND GRAND RIVER.



MAP OF PART OF DAKOTA, WEST OF THE MISSOUR
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MAP
OF PART OF THE
GREAT SIOUX RESER
BETWEEN THE
GRAND AND MOREAU RI
DAKOTA.

F. J. KNIGHT, Topographer

DEPARTMENT OF THE INTERIOR

BULLETIN

OF THE

UNITED STATES

GEOLOGICAL SURVEY

No. 22

ON NEW CRETACEOUS FOSSILS FROM CALIFORNIA

WASHINGTON
GOVERNMENT PRINTING OFFICE
1885

ADVERTISEMENT.

[Bulletin No. 22.]

The publications of the United States Geological Survey are issued in accordance with the statute, approved March 3, 1879, which declares that—

"The publications of the Geological Survey shall consist of the annual report of operations, geological and economic maps illustrating the resources and classification of the lands, and reports upon general and economic geology and paleontology. The annual report of operations of the Geological Survey shall accompany the annual report of the Secretary of the Interior. All special memoirs and reports of said Survey shall be issued in uniform quarto series if deemed necessary by the Director, but otherwise in ordinary octavos. Three thousand copies of each shall be published for scientific exchanges and for sale at the price of publication; and all literary and cartographic materials received in exchange shall be the property of the United States and form a part of the library of the organization: And the money resulting from the sale of such publications shall be covered into the Treasury of the United States."

On July 7, 1882, the following joint resolution, referring to all Government publications, was passed by Congress:

"That whenever any document or report shall be ordered printed by Congress, there shall be printed in addition to the number in each case stated, the 'usual number' (1,900) of copies for binding and distribution among those entitled to receive them."

Under these general laws it will be seen that none of the Survey publications are furnished to it for gratuitous distribution. The 3,000 copies of the Annual Report are distributed through the document rooms of Congress. The 1,900 copies of each of the publications are distributed to the officers of the legislative and executive departments and to stated depositories throughout the United States.

Except, therefore, in those cases where an extra number of any publication is supplied to this office by special resolution of Congress, as has been done in the case of the Second, Third, Fourth, and Fifth Annual Reports, or where a number has been ordered for its use by the Secretary of the Interior, as in the case of Mineral Resources and Dictionary of Altitudes, the Survey has no copies of any of its publications for gratuitous distribution.

ANNUAL REPORTS.

Of the Annual Reports there have been already published:

I. First Annual Report to the Hon. Carl Schurz, by Clarence King. 1880. 8°. 79 pp. 1 map.—A preliminary report describing plan of organization and publications.

II. Report of the Director of the United States Geological Survey for 1880–'81, by J. W. Powell. 1882. 8°. lv, 588 pp. 61 pl. 1 map.

III. Third Annual Report of the United States Geological Survey, 1881–'82, by J. W. Powell. 1883 8°. xviii, 564 pp. 67 pl. and maps.

IV. Fourth Annual Report of the United States Geological Survey, 1882–'83, by J. W. Powell. 1884. 8°. xii, 473 pp. 85 pl. and maps.

The Fifth Annual Report is in press.

MONOGRAPHS.

Of the Monographs, Nos. II, III, IV, V, VI, VII, and VIII are now published, viz:

II. Tertiary History of the Grand Cañon District, with atlas, by Clarence E. Dutton, Capt., U. S. A. 1882. 4°. xiv, 264 pp. 42 pl. and atlas of 24 sheets folio. Price $10.12.

III. Geology of the Comstock Lode and the Washoe District, with atlas, by George F. Becker. 1882. 4°. xv, 422 pp. 7 pl. and atlas of 21 sheets folio. Price $11.

IV. Comstock Mining and Miners, by Eliot Lord. 1883. 4°. xiv, 451 pp. 3 pl. Price $1.50.

V. Copper-bearing Rocks of Lake Superior, by Roland D. Irving. 1883. 4°. xvi, 464 pp. 15 l. 29 pl. Price $1.85.

VI. Contributions to the Knowledge of the Older Mesozoic Flora of Virginia, by Wm. M. Fontaine. 1883. 4°. xi, 144 pp. 54 l. 54 pl. Price $1.05.

VII. Silver-lead Deposits of Eureka, Nevada, by Joseph S. Curtis. 1884. 4°. xiii, 200 pp. 16 pl. Price $1.20.

VIII. Paleontology of the Eureka District, by Charles D. Walcott. 1884. 4°. xiii, 298 pp. 24 l. 24 pl. Price $1.10.

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The following are in press, viz:

IX. Brachiopoda and Lamellibranchiata of the Raritan Clays and Greensand Marls of New Jersey, by Robert P. Whitfield. 1885. 4°. ix, 338 pp. 35 pl.

X. Dinocerata. A Monograph of an Extinct Order of Gigantic Mammals, by Othniel Charles Marsh. 1886. 4°. —, — pp. 56 pl.

XI. Geological History of Lake Lahontan, a Quaternary Lake of Northwestern Nevada, by Israel Cook Russell. 1885. 4°. —, — pp. 46 pl.

The following are in preparation, viz:

I. The Precious Metals, by Clarence King.

Geology and Mining Industry of Leadville, with atlas, by S. F. Emmons.

Geology of the Eureka Mining District, Nevada, with atlas, by Arnold Hague.

Lake Bonneville, by G. K. Gilbert.

Sauropoda, by Prof. O. C. Marsh.

Stegosauria, by Prof. O. C. Marsh.

BULLETINS.

The Bulletins of the Survey will contain such papers relating to the general purpose of its work as do not properly come under the heads of ANNUAL REPORTS or MONOGRAPHS.

Each of these Bulletins will contain but one paper and will be complete in itself. They will, however, be numbered in a continuous series, and will in time be united into volumes of convenient size. To facilitate this each Bulletin will have two paginations, one proper to itself and another which belongs to it as part of the volume.

Of this series of Bulletins Nos. 1 to 22 are already published, viz:

1. On Hypersthene-Andesite and on Triclinic Pyroxene in Augitic Rocks, by Whitman Cross, with a Geological Sketch of Buffalo Peaks, Colorado, by S. F. Emmons. 1883. 8°. 42 pp. 2 pl. Price 10 cents.

2. Gold and Silver Conversion Tables, giving the coining value of Troy ounces of fine metal, etc., by Albert Williams, jr. 1883. 8°. ii, 8 pp. Price 5 cents.

3. On the Fossil Faunas of the Upper Devonian, along the meridian of 76° 30′, from Tompkins County, New York, to Bradford County, Pennsylvania, by Henry S. Williams. 1884. 8°. 36 pp. Price 5 cents

4. On Mesozoic Fossils, by Charles A. White. 1884. 8°. 36 pp. 9 pl. Price 5 cents.

5. A Dictionary of Altitudes in the United States, compiled by Henry Gannett. 1884. 8°. 325 pp. Price 20 cents.

6. Elevations in the Dominion of Canada, by J. W. Spencer. 1884. 8°. 43 pp. Price 5 cents.

7. Mapoteca Geologica Americana. A catalogue of geological maps of America (North and South), 1752–1881, by Jules Marcou and John Belknap Marcou. 1884. 8°. 184 pp. Price 10 cents.

8. On Secondary Enlargements of Mineral Fragments in Certain Rocks, by R. D. Irving and C. R. Vanhise. 1884. 8°. 56 pp. 6 pl. Price 10 cents.

9. A Report of work done in the Washington Laboratory during the fiscal year 1883–'84. F. W. Clarke, chief chemist; T. M. Chatard, assistant. 1884. 8°. 40 pp. Price 5 cents.

10. On the Cambrian Faunas of North America. Preliminary studies by Charles Doolittle Walcott. 1884. 8°. 74 pp. 10 pl. Price 5 cents.

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ON

NEW CRETACEOUS FOSSILS

FROM

CALIFORNIA

BY

CHARLES A. WHITE M. D.

WASHINGTON
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1885

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ON NEW CRETACEOUS FOSSILS FROM CALIFORNIA.

By Charles A. White.

GENERAL REMARKS.

In Bulletin No. 15 I referred to certain Cretaceous strata which are found in Mendocino County, California, and Todos Santos Bay, Lower California, as belonging to a series which probably occupy a position between the Chico and Shasta Groups. I have not had an opportunity to personally examine the strata at either of the localities referred to, but those of Mendocino County have been examined by Dr. G. F. Becker, of the U. S. Geological Survey, and he has submitted to me for examination a small collection of fossils which he obtained there. Two or three small collections have also been sent to the U. S. National Museum from the Todos Santos Bay locality by Mr. C. R. Orcutt, of San Diego. Owing to the generally disturbed condition of the strata of the Pacific coast region and the limited exposures of the strata in question, comparatively little has been learned as to their relations with the other formations of that region. Dr. Becker found the strata of Mendocino County to consist of a large series of sandstones and sandy shales, with some argillaceous layers. He reports the series there to reach some thousands of feet in thickness, and in general aspect and composition to closely resemble the Chico Group as it is known in California. The exposures which he examined extend from a little north of the town of Wallala[1] to the neighborhood of Fort Ross; and the fossils which he collected from those strata were found near the water's edge upon the shore of the Pacific Ocean, presumably near the base of the series. He found those strata resting unconformably upon a metamorphic series which he believes to be equivalent with the Knoxville beds of the Shasta Group, but he was unable to discover any contact with the strata above them.

The strata at the Todos Santos Bay locality, which upon paleontological grounds I regard as equivalent with the Wallala beds, appear from Mr. Orcutt's notes accompanying his collections to be only slightly exposed there. The locality is about 60 miles south of the southern boundary of the State of California, at the southern shore of the Bay, and at the base of a sea-cliff some 40 or 50 feet in height. The layer from which Mr. Orcutt obtained the fossils which are described in this bulletin has an exposed thickness of only some 5 or 6 feet, and it is so near the water's edge as to be nearly reached by the tides. From Mr. Orcutt's notes I infer that the whole cliff exposure there does not belong to the same formation, but at present I have no other information than that above given.

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[1] This is regarded as the correct spelling by Dr. Becker, but upon some maps the spelling is given as Gualala, and by some persons the name is spelled Walhalla.

Since so little is known of the stratigraphical relations of the Wallala and San Diego beds with other formations, I cannot now discuss them fully, but I shall give them the provisional name of the Wallala Group, referring those of both localities to one and the same formation. Their present discussion must necessarily be mainly paleontological; and although the collections are comparatively so small, they are, in my opinion, of more than usual interest. They indicate a fauna which, while it is of decidedly Cretaceous character, seems to be quite different from any Cretaceous fauna hitherto known upon the Pacific coast.

Although the two localities at which the strata of the Wallala Group have been found exposed are more than 500 miles apart, and no other strata bearing a similar fauna are known in all that region, I feel quite confident that they are not only equivalent with each other, but that they represent a formation which has not hitherto been recognized. Still, the collections which have been made are too small to warrant the publication of such an opinion with that confidence which the study of large collections would give.

The specimens sent by Dr. Becker are all in a bad state of preservation, and a part of them have therefore been determined only generically. The following is a list of them: *Coralliochama orcutti* (n. s.), *Ostrea*, *Inoceramus*, *Pecten*, *Cylichna*, *Turritella*, and *Solarium wallalense* (n. s.). The *Solarium* and *Coralliochama* are described and figured as new species in this bulletin, the latter as the type of a new genus. The *Inoceramus* is a large discoid form, some of the examples having had a diameter of nearly or quite 30 centimeters. All the specimens of this species, however, like those of the remaining members of the foregoing list, are too imperfect to allow of more than generic identification.

The specimens which Mr. Orcutt has sent to the National Museum are in a better state of preservation than those of the Wallala locality. They represent the following species: *Coralliochama orcutti*, *Nerita* ——— ?, *Cerithium pillingi* (n. s.), *C. totium-sanctorum* (n. s.), and *Trochus* (*Oxystele*) *euryostomus* (n. s.). Besides these, there are certain fragments in the collection which indicate the existence of other species. Indeed it is evident that all the fossils which have yet been found at both the Wallala and San Diego localities represent only a small part of the fauna to which they originally belonged. They are, however, regarded as of sufficient importance to warrant their publication in the present form. They represent at least five new species and one new genus; and they seem also to represent the fauna of a Cretaceous for-n which has not heretofore been recognized. The character of fossils seems to indicate for them the age of the Middle Cretaceous; n some respects they remind one of the Gosau formation of Europe.

CHAMIDÆ.

Genus CORALLIOCHAMA (nov. gen.),

hells fixed by the apex of the lower, or right, valve, growing separately or in clusters. Test thick, consisting of three layers, the outer being prismatic, the middle cellular, and the inner porcellanous. space which was occupied by the animal was very small as compared with the bulk of the shell, and it is situated eccentrically. Lower lve irregularly subconical, more or less distorted, much deeper than other valve; beak distorted as a consequence of its attachment to foreign object; ligamental groove more or less distinct, extending om the apex to the hinge margin. Upper valve convex, its beak oad and incurved to the hinge margin of the lower valve; ligamental oove marginal; internal cavity partially divided into unequal parts a more or less prominent longitudinal septum. Hinge essentially same as that of *Plagioptychus* Matheron, *Ichthyosarcolithes* Desmast, and *Caprina* d'Orbigny.

The test of both valves consists of a thin outer prismatic layer, a thick llular middle layer, and a thin porcellanous inner layer. The middle layer constitutes the bulk of both valves. In the lower valve it consists of slender angular thin-walled tubes which extend the full length of the valve, increasing in number with the increasing size of the shell, each tube being divided into small cells by numerous thin transverse partitions. The structure thus produced somewhat resembles that of a coral of the Favositidæ, and it is also closely similar to that of corresponding parts of *Radiolites* and *Sphærulites*. The inner portion of the middle layer of the upper valve has the same cellular structure as that which has just been described for the lower valve, except that the longitudinal arrangement of the cells is not so evident; and the teeth of both valves are mainly or wholly composed of shell-substance which possesses this cellular structure. The outer portion of the middle layer of the upper ve, however, has a structure similar to that which is possessed by the er valve of Plagioptychus. It consists of numerous thin, close-set ating vertical plates or septa which extend from the beak to the free rgin, their outer edges abutting against the outer prismatic layer, and their inner edges they blend with the inner cellular portion of the ddle layer.

This proposed new genus stands near to *Plagioptychus*, *Ichthyosarcothes*, and *Caprina*, agreeing with them all in the general character of the hinge and of the ligamental grooves, and in the prese[illegible] prismatic shell-layer. It further agrees with *Plagiotychus* [illegible] ure of the outer portion of the middle shell-layer of the upper valve; but it disagrees with that genus in the multicellular structure of the thick middle layer of the lower valve, and that of the inner portion of the middle layer of the upper valve; those portions being porcellanous in *Plagioptychus*.[2] Comparing the shell-structure of *Coralliochama* with that of *Ichthyosarcolithes*, the cells of the former are seen to be much more uniform in size; and the large so-called water-chambers in the thick shell-walls of the latter are wanting in those of the former. Also the slender radiating plates or septa of the outer portion of the middle layer of both *Coralliochama* and *Plagioptychus* are apparently wanting in *Ichthyosarcolithes*. At least such a structure seems never to have been described.

It is quite evident, however, that there is homological relationship between *Caprina*, *Plagioptychus*, *Ichthyosarcolithes*, and *Coralliochama*, as regards the cellular character of their shells. The radiating canals of the upper valve of *Caprina* (which seem to be foreshadowed in *Monopleura* by a radiate striation that is sometimes observable), may thus be compared with the narrower interspaces between the radiating septa which characterize the upper valve of *Plagioptychus* and of *Coralliochama*. In like manner the simple so-called water-chambers of the lower valve of *Caprina* may be compared with the complex cellular structure of the corresponding valve of *Ichthyosarcolithes* and of *Coralliochama*, reaching the maximum of subdivision, if not of complexity, in the latter genus.

Coralliochama orcutti (sp. nov.)

(Plates I, II, III, and IV.)

Sphærulites ? White, 1885, Bull. U. S. Geol. Survey No. 15, page 27

Shell reaching a large size, growing both singly and in clusters, one example in the collection showing a cluster of eight individuals. Lower valve irregularly subpyramidal, usually much elongated and more or less distorted; its free border transverse or oblique, the posterior side in the latter case being the lower; ligamental groove somewhat distinct; the space which was occupied by the animal comparatively small, eccentric, the thinnest portion of the shell-wall being at the part which

---

[2] It is proper to remark that in all these comparisons with the genera named, I have had in mind the emended generic diagnoses which are given in Zittel and Schimper's Handbuch der Palæontologie; and which seem to me to be correctly set forth by those authors. The genus *Plagioptychus* has not hitherto been known in North America, and I have not had an opportunity to examine the shell-structure of authentic specimens of that genus; but I cannot believe that those eminent savants would have overlooked in *Plagioptychus* such a multicellular structure as characterizes the genus here proposed, and which is its distinguishing characteristic. It will be seen that this proposed new genus rests mainly or wholly upon the multicellular structure of the principal part of the shell; and that this structure is in especial contrast with the porcellanous texture of the corresponding parts of *Plagioptychus*.

corresponds to the postero-basal part in ordinary bivalves. Surface, when the outer prismatic layer is present, marked by fine longitudinal lines, and somewhat more distinct concentric lines of growth. The coarser markings of the valve consist of a greater or less number of concentric undulations, which are crossed by longitudinal corrugations that are usually more conspicuous upon the side which bears the hinge, especially the part adjacent to the hinge margin. The prismatic layer is moderately thin, and is composed of minute vertical prisms which are visible only under a lens. The middle shell-layer reaches a maximum thickness in old shells of nearly or quite 30^{mm}. This layer is composed throughout of a mass of very small, angular thin-walled cells. The cells have a good degree of uniformity of size, their longitudinal arrangement and angular shape being quite distinctly seen by side view of weathered specimens. By vertical view they are seen to be of irregular shape and arrangement, but concentric lines of accretion are sometimes observable in cross sections of the valve. The inner porcellanous layer is thin, and under a lens it is seen to consist of numerous concentric laminæ.

The upper valve is broadly convex, becoming large and strongly arched in old shells; beak prominent, broad, incurved and usually directed a little forward, but sometimes it has a slight backward inclination. Surface, when the outer prismatic layer is present, having an approximately smooth aspect; but it is marked by numerous lines of growth and a multitude of very fine radiating lines. Specimens having the prismatic layer exfoliated or weathered off show the edges of the numerous close-set radiating septa of the outer portion of the middle layer. These septa are moderately deep, and are so joined together by their inner edges in pairs and double pairs, that the innermost spaces between them are wider than those which appear at the outer surface of the layer. The inner portion of the middle layer has a structure essentially the same as that which the whole of the middle layer of the lower valve possesses, but at the thinnest portion of the upper valve this cellular portion of the middle layer is obsolete or wanting especially in young shells. The fact that the specimens of this collection are so frequently crushed by pressure shows that they were not so strong as their great thickness would indicate.

All the details of the hinge have not been clearly ascertained. The principal tooth of the lower valve is known to have been very large and prominent, filling a large part of the space upon the posterior side of the septum of the upper valve. The anterior tooth of the upper valve is not well defined from the cardinal end of the septum, but the posterior tooth is narrow, prominent, comparatively long, and curved outward.

Fully adult shells reached a length of more than 200^{mm}, and a diameter at the free margins of 90^{mm} or more.

Upon a preliminary examination of the collections sent by Mr. Orcutt, and the less perfect examples obtained by Dr. Becker, owing to the multicellular structure of the shell, which was conspicuously seen, I regarded this form as belonging to the genus *Sphærulites*. But after a more careful study, and working a separated upper valve out of its imbedding matrix, it was found to possess the hinge-structure that has just been described. The specific name is given in honor of Mr. C. R. Orcutt, who first discovered it. (Museum No. 12698.)

Locality: Shore of Todos Santos Bay, Lower California; and near the town of Wallala, Mendocino County, California.

TROCHIDÆ.

Genus TROCHUS Linnæus.

Subgenus OXYSTELE Philippi.

Trochus (Oxystele) euryostomus (sp. nov.).

(Plate V, Figs. 9, 10, and 11.)

Shell small, depressed-subturbinate; volutions about four in number, rounded, and, at the distal border, more or less distinctly appressed against the preceding volution; aperture comparatively large, and, in adult shells, the inner lip is appressed against the last volution as a callus covering of a portion of the base of the shell, but its margin being a little elevated, it forms, together with the thin outer lip, a continuous margin to the aperture. In immature shells the callus of the inner lip is not formed, and the margin of the aperture is therefore not then continuous. Surface marked by numerous sharply raised revolving, somewhat crenulated ridges, separated by grooves of similar width. (Museum No. 13410.)

Height, 6mm; greatest diameter of the last volution, 8mm.

Locality: Shore of Todos Santos Bay, Lower California.

NERITIDÆ.

Genus NERITA Linnæus.

Nerita——?

(Plate V, Figs. 7 and 8.)

Among the fossils which Mr. Orcutt obtained at the Todos Santos Bay locality are a few examples of a small species of *Nerita*. The largest examples are only some 5 or 6mm in diameter, and, although nearly perfect, they do not possess sufficiently salient features to enable one to diagnose them satisfactorily from the very numerous simple forms of that genus already known. (Museum No. 13411.)

CERITHIIDÆ.

Genus CERITHIUM Bruguiere.

Cerithium pillingi (sp. nov.).

(Plate V, Figs. 3, 4, 5, and 6.)

Shell small; spire comparatively short; volutions four or five in number; each volution bearing four or five prominent longitudinal folds, which are usually so arranged upon the spire as to form continuous ridges along its whole length. These long ridges, together with the flattening of the sides of the volutions between them, give a distinctly angular aspect to the shell. Volutions marked by numerous revolving crenulated or tuberculated coarse lines or slender ridges, and the anterior side of the last one is marked in a similar manner; suture not readily distinguishable from the interspaces between the revolving ridges of the spire; aperture, when occurring between the longitudinal folds, comparatively small; beak short; canal narrow.

Height of the largest example in the collection, 12^mm^; greatest diameter of the last volution, 7^mm^.

In general aspect, this shell resembles the *C. sexangulatum* of Zekeli from the Gosau formation of Europe, but it differs from that species in being proportionally shorter, in the character of its revolving ridges, and in having the spaces between the longitudinal folds upon the spire more flattened.

The specific name is given in honor of Mr. J. C. Pilling, of the United States Geological Survey. (Museum No. 13408.)

Locality: Shore of Todos Santos Bay, Lower California.

Cerithium totium-sanctorum (sp. nov.).

(Plate V, Figs. 12 and 13.)

Shell small, slender; sides of the spire straight or slightly concave; volutions eleven or twelve in number, not convex; each volution marked by four tuberculated revolving ridges, the anterior one being usually a little more prominent than the other three; at irregular and somewhat wide intervals upon the volutions there are moderately prominent longitudinal folds which are sometimes arranged approximately in rows along the spire, but they are as often scattered; suture impressed, its presence being indicated by a space between the revolving ridges which is a little wider than the other spaces; anterior side of the last volution marked by small revolving ridges, but they are crenulated and not tuberculate like those upon the sides of the spire; beak moderately small; canal narrow.

Length, 20^mm^; diameter of the last volution, 7^mm^. (Museum No. 13409.)

Locality: Shore of Todos Santos Bay, Lower California.

SOLARIIDÆ.

Genus SOLARIUM Lamarck.

Solarium wallalense (sp. nov.).

(Plate V, Figs. 1 and 2.)

Shell of medium size, depressed; volutions about four in number, increasing somewhat rapidly in size, carinate at the periphery, broadly convex between that carina and the suture; umbilicus of medium size, having an obtuse carina at its margin; the space between the peripheral and umbilical carinas is flattened, and marked by numerous very small obliquely-radiating ridges, the inner surface of the umbilicus also marked by numerous very small radiating lines or ridges which are made crenulate by the presence of numerous revolving lines. The type specimen shows that the volutions of the spire also bore obliquely-crenulated markings, but it has been so much weathered that they are nearly obliterated.

Height, about 17^{mm}; greatest diameter, about 25^{mm}.

The only example that has been obtained is quite imperfect, but it is described and named for the purpose of presenting the fauna of the Wallala Group as fully as practicable. (Museum No. 13412.)

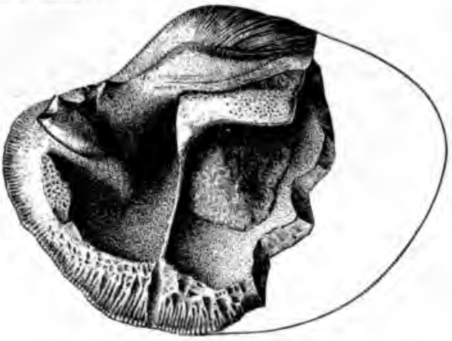
Locality: Near the town of Wallala, Mendocino County, California.

EXPLANATION OF PLATES.

PLATE I.

CORALLIOCHAMA ORCUTTI (page 10).

Fig. 1. View of the cardinal side of a partly grown specimen; natural size.
Fig. 2. Lateral view of the same example.
Fig. 3. Interior view of a broken upper valve, showing the hinge.
Fig. 4. A fragment of a lower valve, showing the cellular structure.
Fig. 5. Another fragment showing the same structure.



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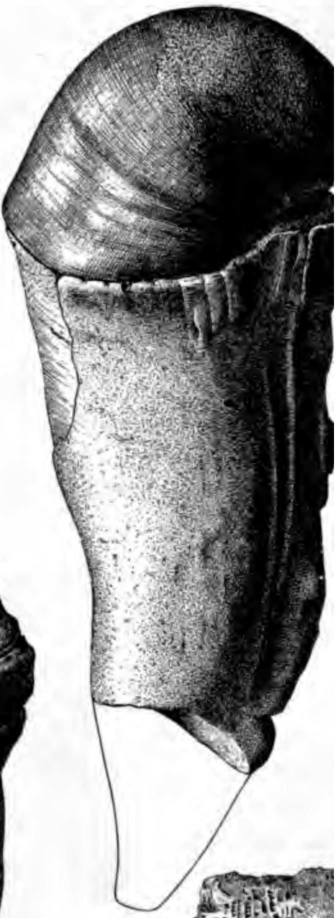

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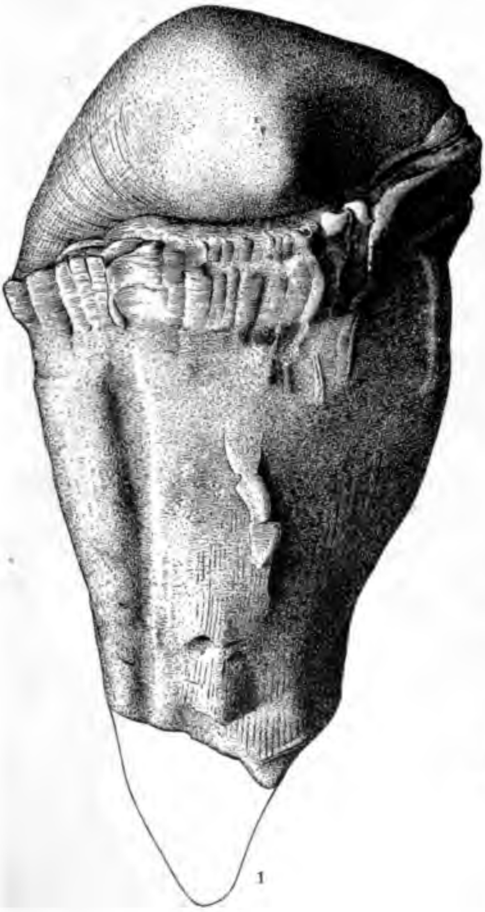

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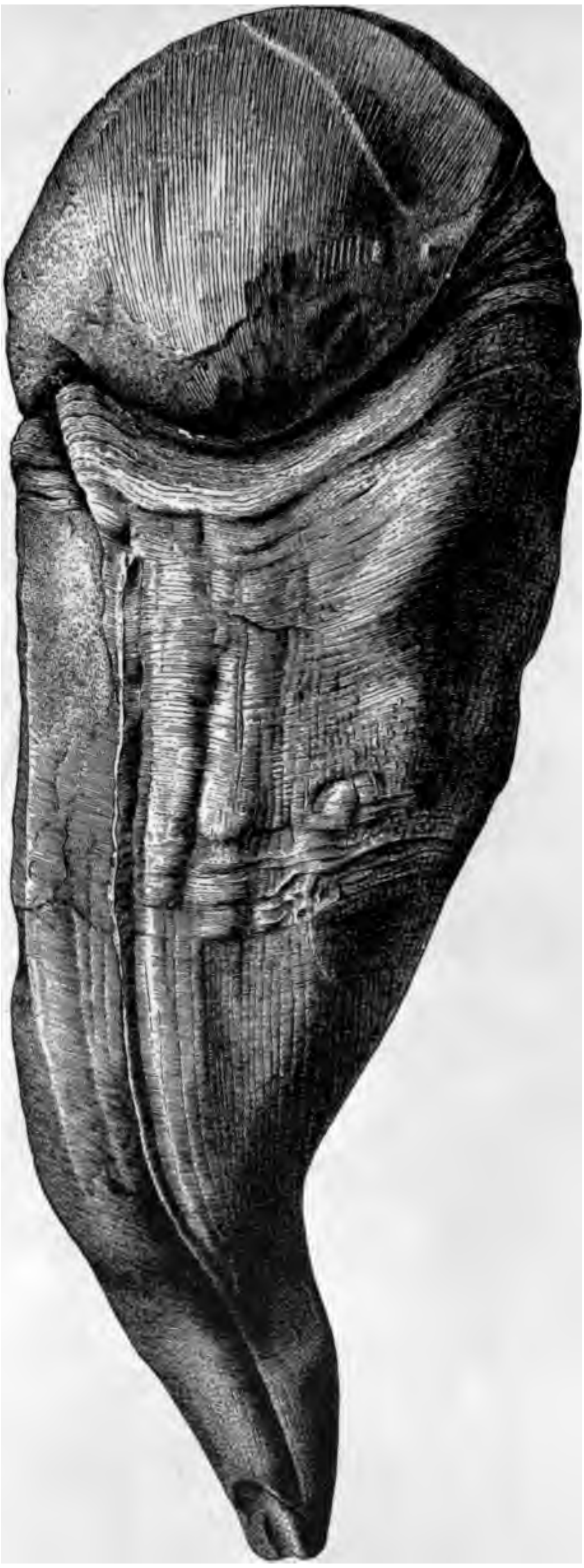
CORALLIOCHAMA ORCUTTI

PLATE II.

CORALLIOCHAMA ORCUTTI (page 10).

Fig. 1. Cardinal view of an adult example; natural size.



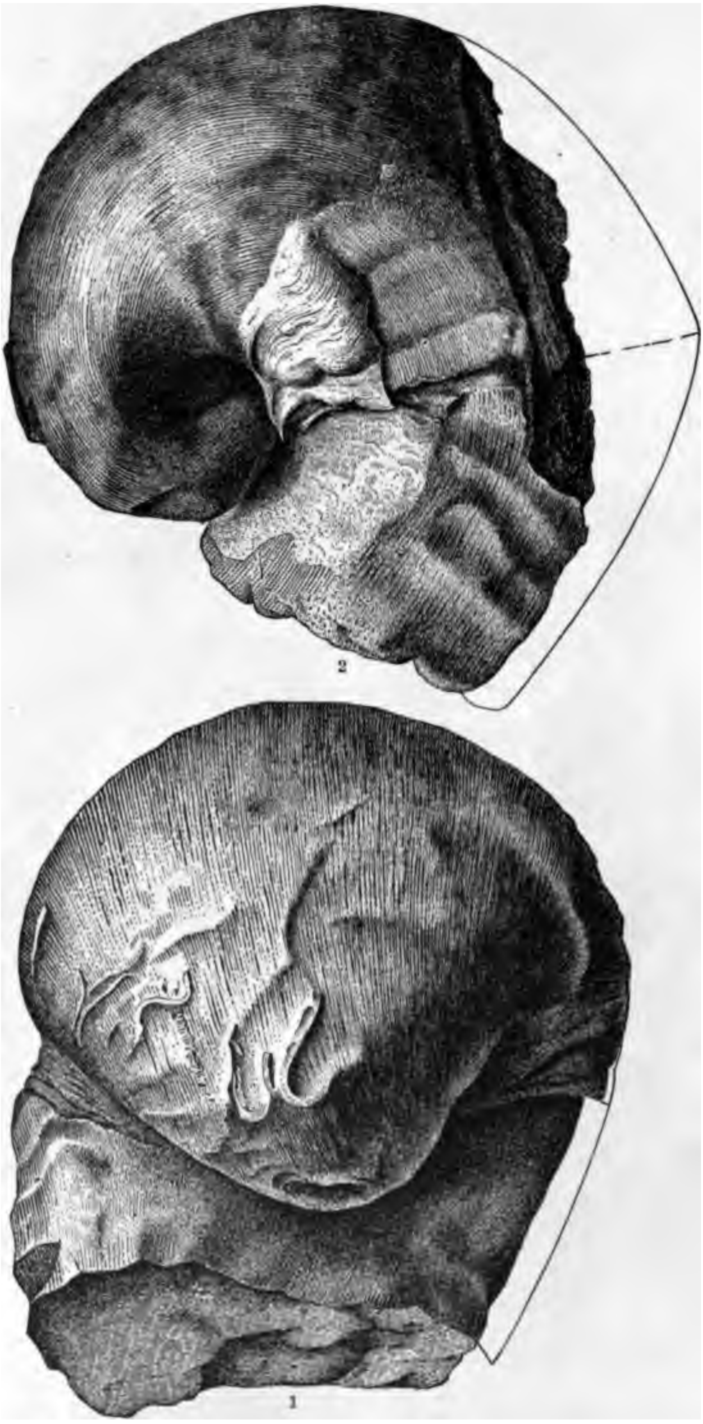
CORALLIOCHAMA ORCUTTI

PLATE III.

CORALLIOCHAMA ORCUTTI (page 10).

Fig. 1. A fragment of a large example, showing the extreme convexity of the upper valve; natural size.

Fig. 2. Lateral view of the same example.

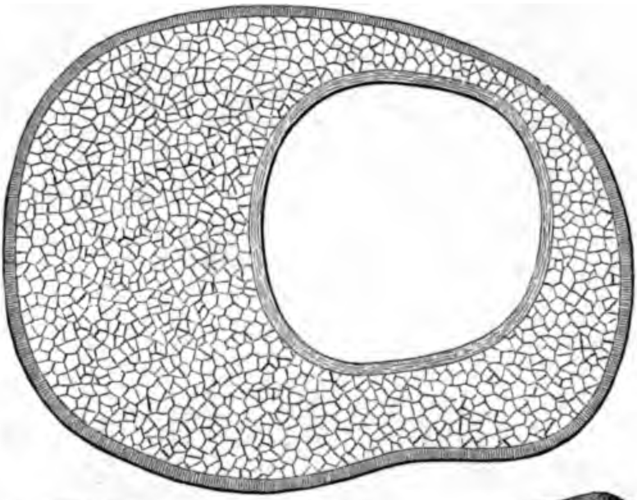


CORALLIOCHAMA ORCUTTI.

PLATE IV.

CORALLIOCHAMA ORCUTTI (page 10).

Fig. 1. Cardinal view of a partly grown example; natural size.
Fig. 2. Opposite view of another example.
Fig. 3. Section of a portion of an upper valve, showing the outer prismatic layer, the inner porcellanous layer, and the cellular inner layer, with the vertical plates of the outer portion of the latter layer. Partly diagrammatic; natural size.
Fig. 4. Diagram of a transverse section of a lower valve, showing the outer prismatic layer, the inner porcellanous layer, and the middle cellular layer.



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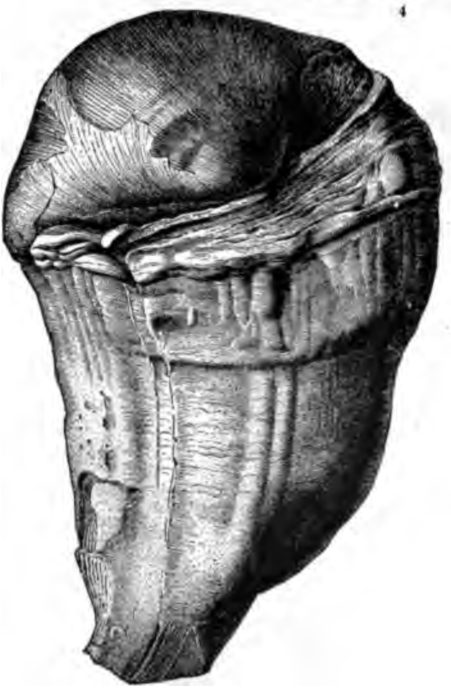

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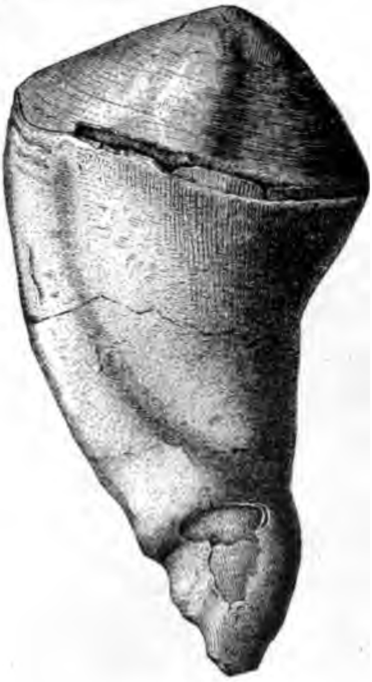

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CORALLIOCHAMA ORCUTTI

PLATE V.

SOLARIUM WALLENSIS (page 14).

Fig. 1. Lateral view, natural size.
Fig. 2. Umbilical view of the same example.

CERITHIUM PILLINGI (page 13).

Fig. 3. Lateral view, natural size and enlarged.
Fig. 4. Similar views of another example.
Fig. 5. Similar views of a third example.
Fig. 6. Similar views of another example, showing the aperture.

NERITA —— (page 12).

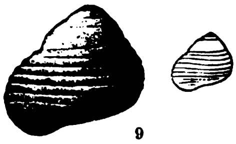
Fig. 7. Lateral view, natural size and enlarged, showing original color-markings.
Fig. 8. Similar views, showing the aperture and inner lip. These examples were received after the notice of the species on page 12 was printed. They are sufficiently perfect to warrant the application of a new name. I therefore propose the name *Nerita californiensis.*

TROCHUS (OXYSTELE) EURYOSTOMUS (page 12).

Fig. 9. Lateral view, natural size and enlarged.
Fig. 10. Basal view of the same example, showing aperture and callous inner lip.
Fig. 11. Lateral view of another example not quite mature, and in which the inner lip had not become thickened.

CERITHIUM TOTIUM SANCTORUM (page 12).

Fig. 12. Lateral view, natural size and enlarged, of a nearly perfect example.
Fig. 13. Similar view of a fragment of another example.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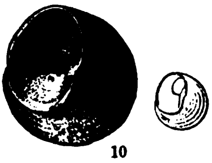
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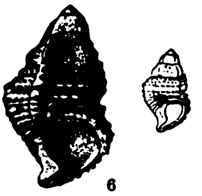
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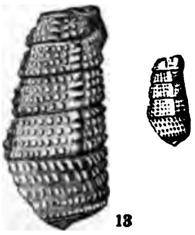
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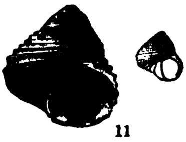
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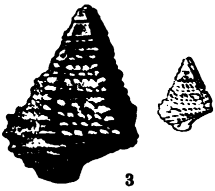
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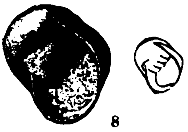
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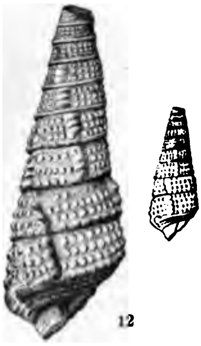
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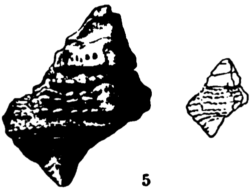
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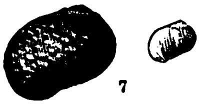
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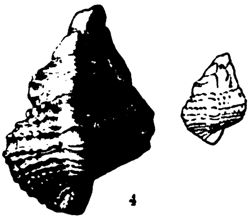
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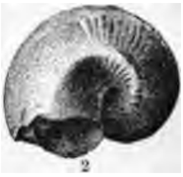
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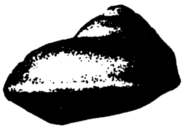
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